

# Instrumentation Division Report

Veljko Radeka

Presentation to the DOE HEP Program Review  
APRIL 22-23, 2004

## Outline

- **Core Technologies and Facilities**
- **Key Accomplishments and R&D for future HEP Program**



managed by Brookhaven Science Associates for the U.S. Department of Energy

# Instrumentation Division

## Mission:

“To develop state-of-the-art instrumentation required for experimental research programs at BNL.

To provide limited production quantities of such instrumentation for BNL-related experiments.”

## Core technologies:

- **Semiconductor detectors** (pixel-, drift-, photo sensors);
- **Gas and noble liquid detectors**;
- **Microelectronics** (low noise analog/digital);
- **Lasers and Optics** (ultra-short photon & electron bunches, photocathodes, optical metrology);
- **Micro/nano Fabrication** (sensors, microstructures, e-beam lithography).

## Staff:

**44 Total (lost 3 in Oct. 2003)**

**24 Scientists & Professionals**

**21 Technical & Administrative**

## Publications in FY 02/03

**All Programs: 43**

# Instrumentation Division

## Core Competencies and Program Areas Served

		<div> Nuclear Physics H. E. Physics Accelerator Dev. Chemistry Material Science Biology &amp; Medicine EENS Industry Collab. </div>							
Semiconductor, Gas & Liquid Detectors	X-ray, gamma-ray Detectors (1D, 2D)					✓	✓	✓	
	High Resolution Neutron Detectors				✓		✓	✓	
	Silicon (strip-, pad-, drift-) Detectors	✓	✓	✓	✓	✓	✓	✓	✓
	Cryogenic Detectors	✓	✓						
	Gas Detectors for High Particle Rates and Multiplicities (Cathode Pad/Strip Chambers)	✓	✓	✓	✓	✓	✓		
Micro-electronics	Monolithic and Hybrid Low Noise Amplifiers	✓	✓	✓	✓	✓	✓	✓	✓
	Data Acquisition Electronics	✓	✓		✓	✓	✓	✓	✓
	Fast Noble Liquid Calorimetry Readout	✓	✓						
Lasers, Optics & Microfabrication	Optics Metrology		✓		✓	✓	✓	✓	✓
	Laser and Optics in New Accelerator Concepts: Photocathodes, Fast Pulsed Photocathodes	✓	✓	✓		✓	✓	✓	✓
	Electro-optics and Ultrashort Laser-pulse Techniques (ps — fs → as )	✓	✓	✓		✓			✓
	Micro/nano Fabrication			✓		✓	✓	✓	✓
Total Effort in FY2003 [%]		35	25	40					

# Program 04-08

## ***In support of vital BNL programs:***

- RHIC Detector Upgrades (silicon and TPC)
- e-cooler; e-RHIC:
  - High Current Photocathodes*
- ATLAS Dets., and LHC upgrade
- Si-detectors for Polarimeters
- Si-detectors & microelectronics:
  - EXAFS at high photon rates*
  - X-ray Microscopy*
  - Protein crystallography*
  - TEAM*
- LSST
- New small animal PETs, MRI
- Neutron detectors for SNS
- Detectors and Microelectronics for  
Homeland Security Program

## ***State-of-the-art core technology:***

- Fine-grained Si and gas detectors
- Low noise microelectronics from submicron to nanoscale
- Femtosecond, photon and particle beam generation & diagnostics
- Nano-fabrication: pattern generation; deposition/ablation; characterization

## ***Exploration:***

- CMOS as direct conversion detectors
- Megapixel matrix on kohm cm Si
- Neutrino (“bubble”) detector
- Femtosecond ~100 eV source

# HEP Activities

## Projects/Experiments:

### ❑ *LHC, with Physics Dept.*

- **ATLAS liquid argon calorimeter:** responsible for *signal integrity, coherent noise, Faraday cage design from the electrodes → feedthroughs → readout crates;*
- **ATLAS Cathode Strip Chambers and low noise electronics for muon detection;**

### ❑ *KOPIO, MECO at AGS:* Si-drift photo diode for calorimeter; calorimeter and tracker electronics;

## R&D for Future Facilities (LHC Lum. upgrade, LC) and programs:

### ❑ *Si-detector technology* (the only facility for U.S. HEP program): • *single-sided 2-d strip detectors; radiation hardness techniques*

### ❑ *Microelectronics*, low noise, submicron-to-nanoscale;

### ❑ *Picosec/femtosec beam diagnostics* for future accelerators.

### ❑ *LSST*

### ❑ *Neutrino Detectors*, new concepts;

# **Silicon Detector Research**

# Si Detector Development and Processing at Instrumentation Div.

## Novel Stripixel detectors

### 2d position sensing, 1-sided

### processing

- Heavy ion detector with submicron 2d position resolution (cell damage studies)
- PHENIX Upgrade (25  $\mu\text{m}$  position resolution in x and y obtained)
- US-ATLAS Upgrade (radiation hard  $\sim 2 \times 10^{15} \text{ n/cm}^2$ )

## Strip detectors

- CERN NA60 (segmented, multi-pitch)
- RHIC PP2PP (large Roman pot)
- AGS/RHIC Polarimeter (wide strips)

## Pixel/pad detectors

- NSLS: multi-element X-ray detectors

## Active matrix pixel sensors

## Edgeless detectors

## Radiation hard/tolerant Si detectors

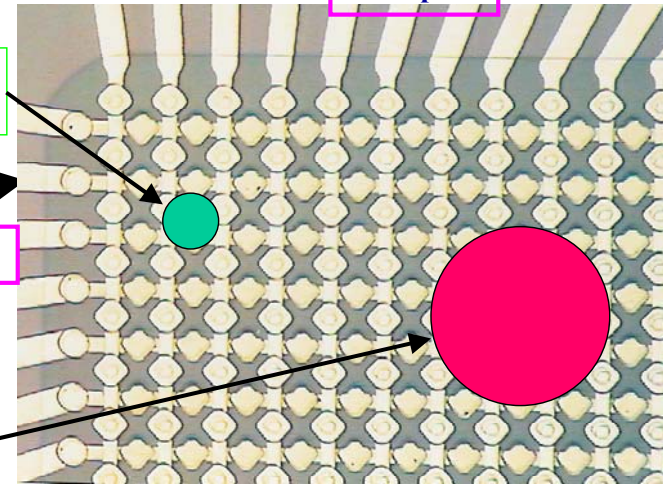
Low resistivity; oxygenated; cryogenic; CZ; Semi-3d; etc.

FWHM of charge Diffusion for MIP

Y-strips

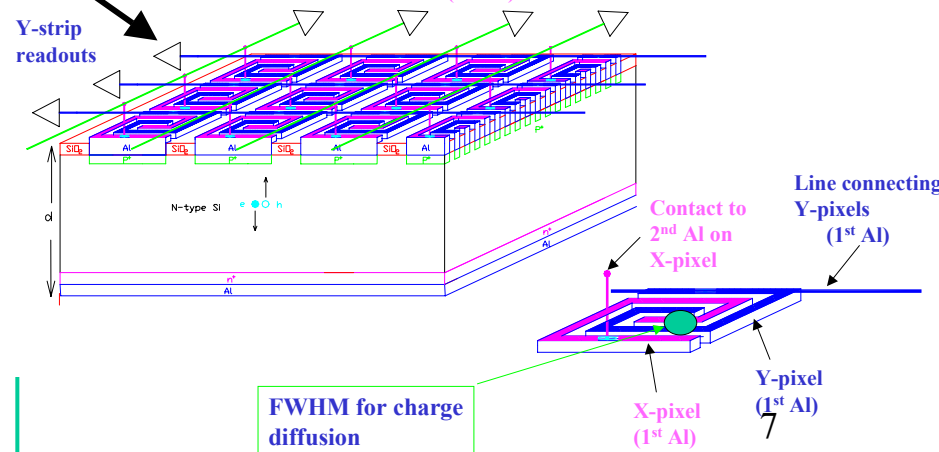
FWHM of charge Diffusion for ions and  $\alpha$

X-strips



20  $\mu\text{m}$

*Schematic of a square spiral interleaving scheme used for PHENIX upgrade*



FWHM for charge diffusion

# Alternating stripixel detectors (ASD)

Individual **pixels** are alternately connected by X and Y readout lines (**strips**)

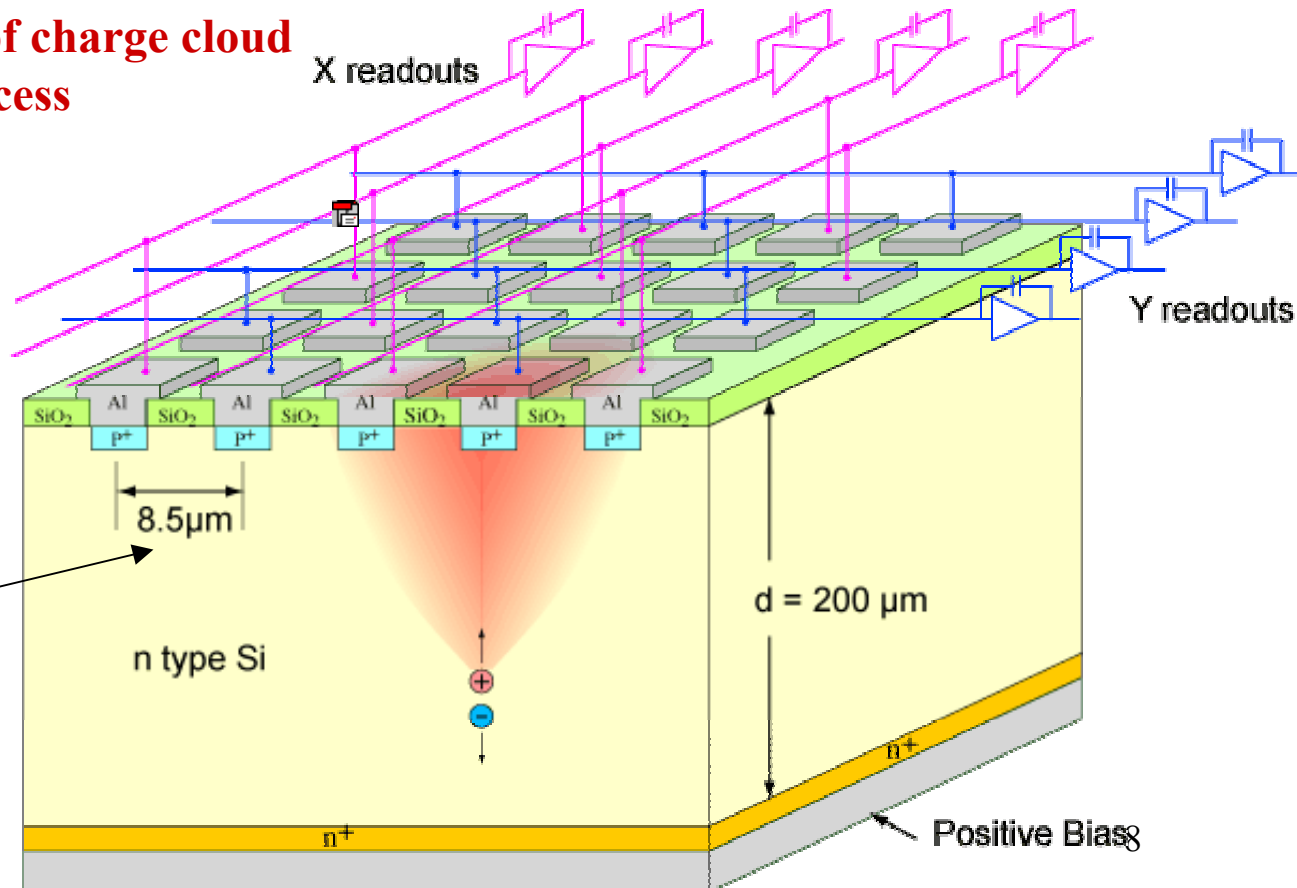
- Two dimensional position sensitivity is achieved by charge sharing between X and Y pixels
- The pixel pitch must not be larger than the size of charge cloud caused by diffusion process

Interpolating readout:

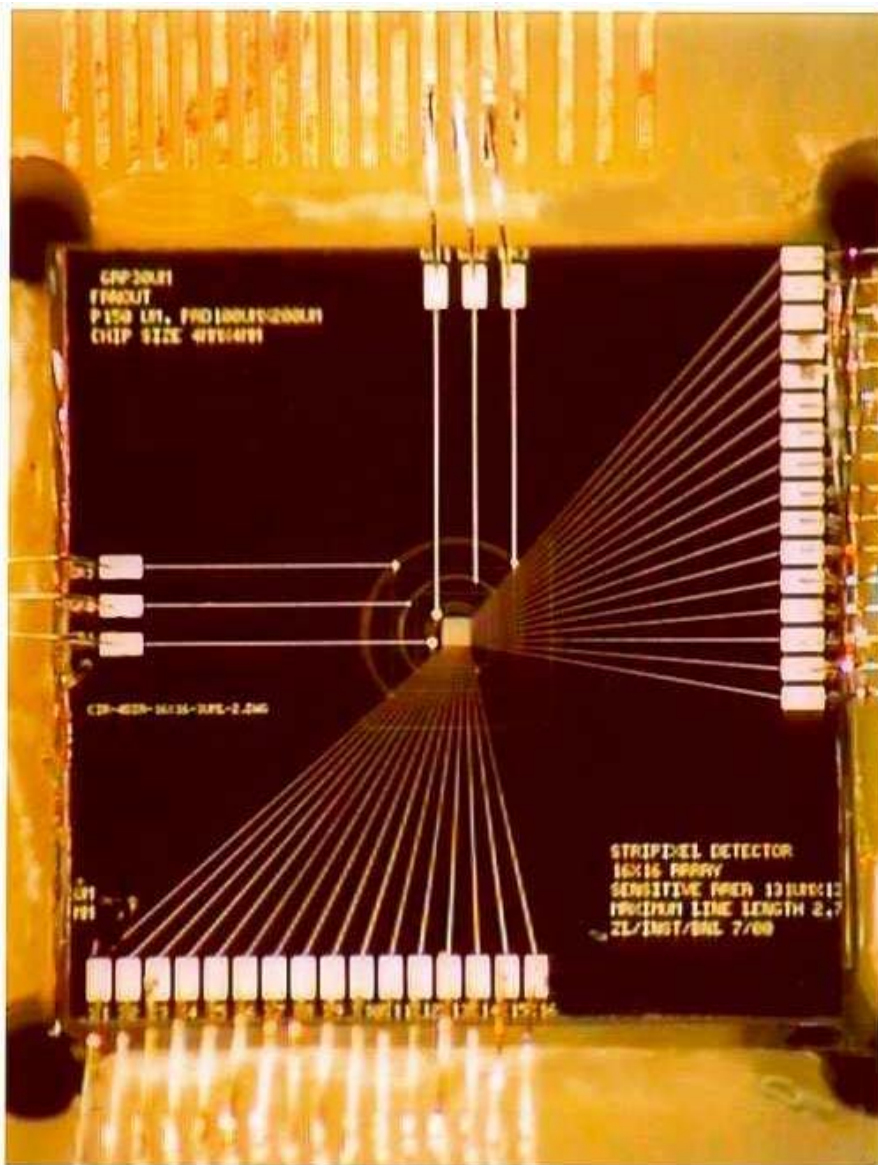
$$\frac{\sigma_x}{w} \approx \frac{2}{S/N}$$

Pixel pitch

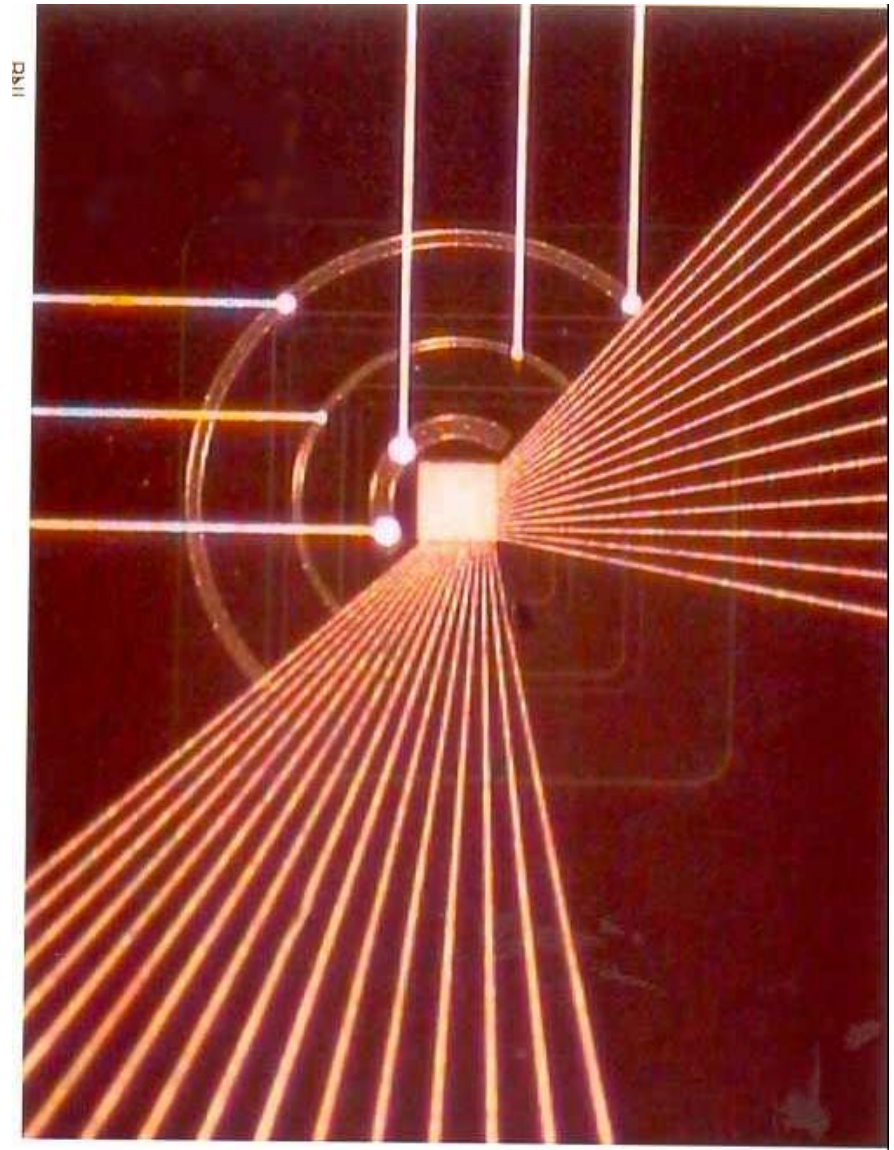
Interpolation factor  $w/\sigma_x \sim 10-100$



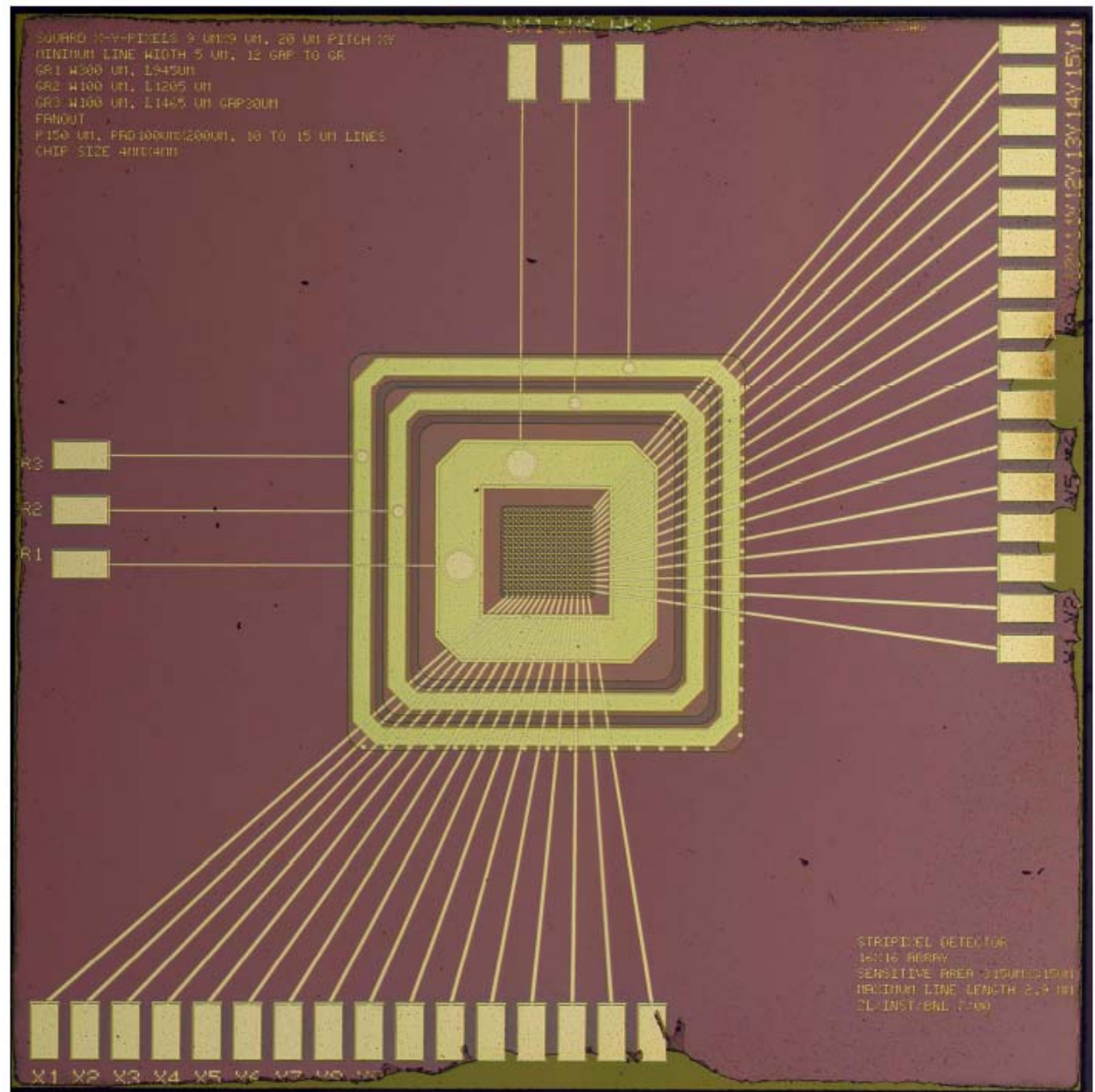
# Detector ("Stripixel") Prototype with Connections Fanout



Chip size: 4x4 mm



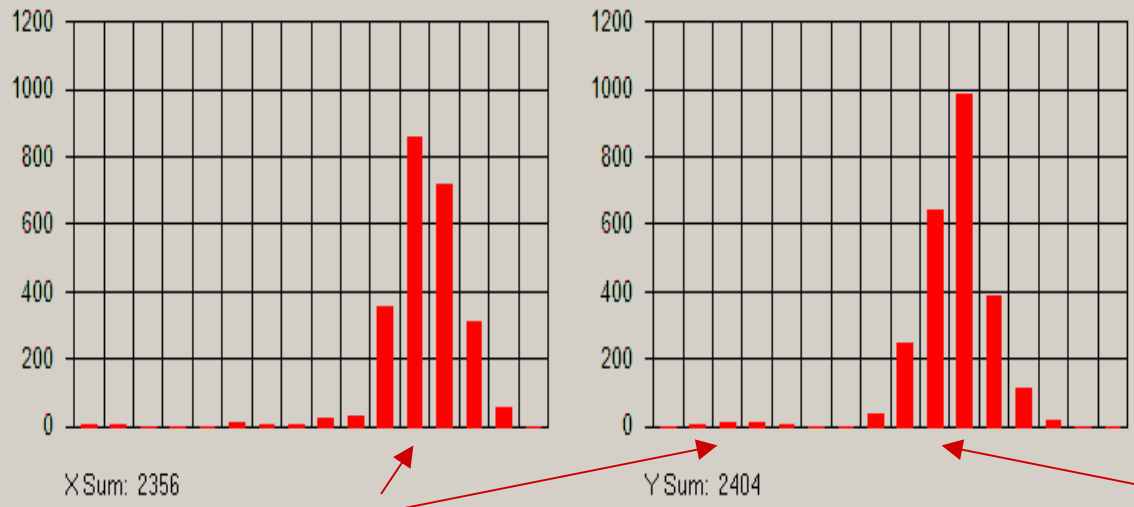
# 4 x 4 mm detector chip with 20 $\mu\text{m}$ readout pitch



# Micron Resolution Detector Tests

Iron ions 1GeV/nucleon:  
total charge in 200  $\mu\text{m}$  Si  
 $\approx 2.6 \text{ pC}$

1 bin  $\equiv 20 \mu\text{m}$



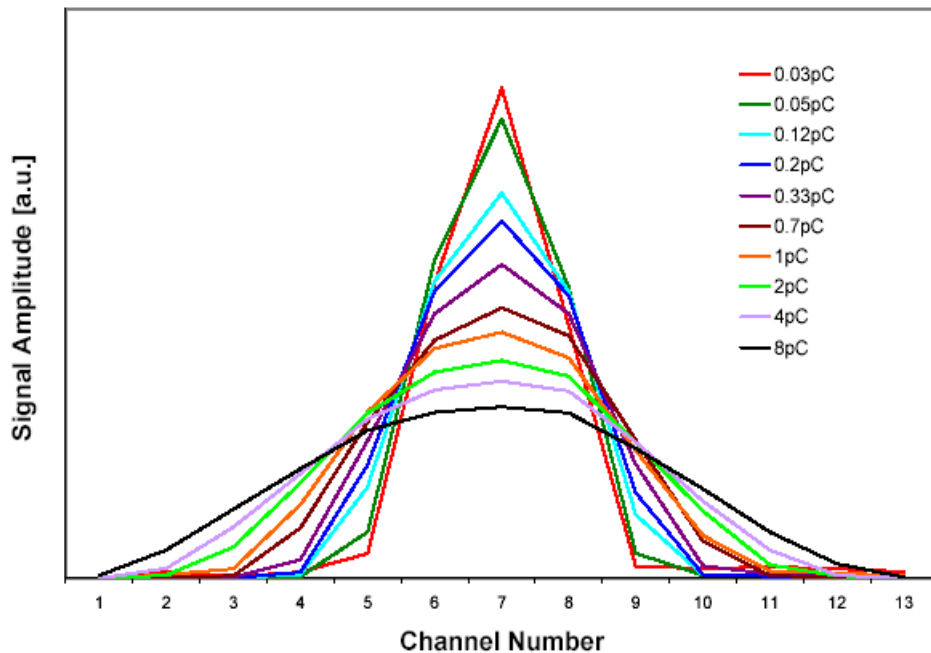
Single ion charge samples in x,y

Laser tests:

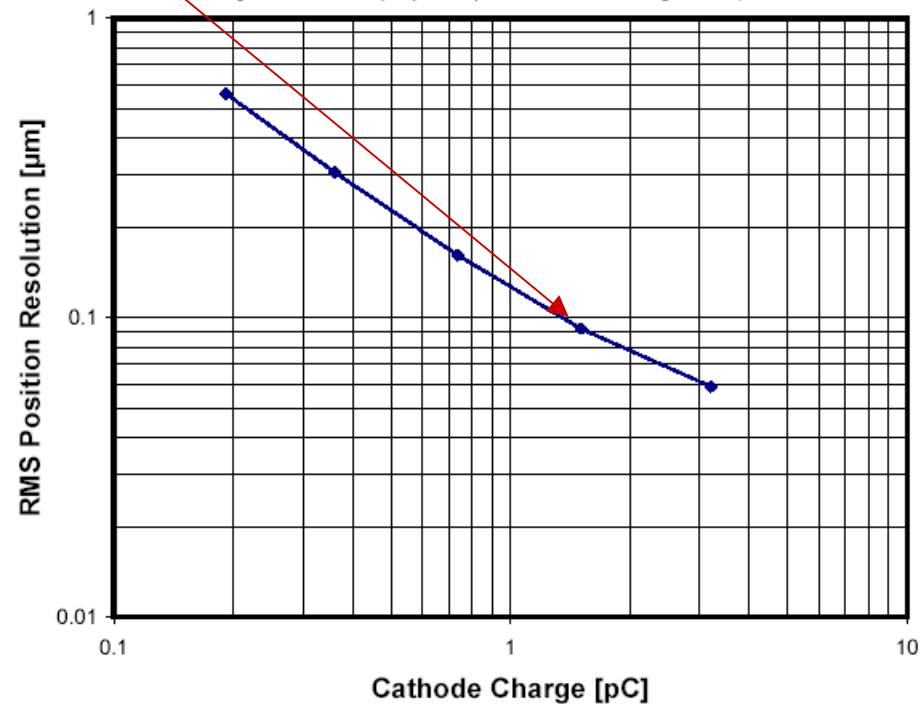
$\sigma_{x,y} \sim 0.1 \mu\text{m}$  at  $\sim 1.4 \text{ pC}$

Charge Spread vs. Charge Level

(20 $\mu\text{m}$  pixel pitch, 650nm laser on back side, 60V bias, normalized area)



Position Resolution vs Cathode Charge  
(20 $\mu\text{m}$  pixel, 650nm laser, 60V bias, 5ch centroid  
low gain driver, 4.7pF preamp feedback, GBLR gain=16)



# Schematics of Novel Interleaved Stripixel Si Detectors for PHENIX Upgrade and US ATLAS Upgrade

## o PHENIX Upgrade

Pixel pitch: 1 mm (X) and 80  $\mu\text{m}$  (Y)

Strip pitch: 80  $\mu\text{m}$  (u) and 80  $\mu\text{m}$  (Y)

Stereo angle between u and Y strips: 4.6  $^\circ$

FZ n-type, detector thickness 400 to 500  $\mu\text{m}$

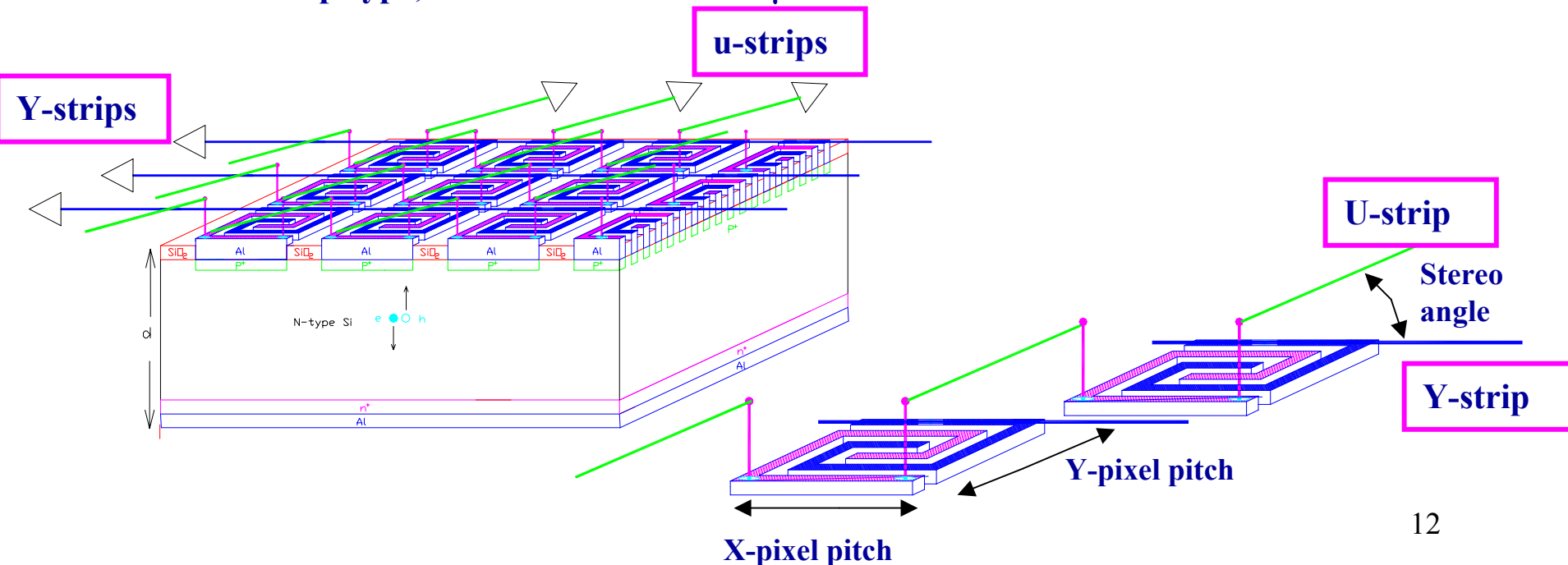
## US-ATLAS Upgrade

Pixel pitch: 620  $\mu\text{m}$  (X) and 50  $\mu\text{m}$  (Y)

Strip pitch: 50  $\mu\text{m}$  (u) and 50  $\mu\text{m}$  (Y)

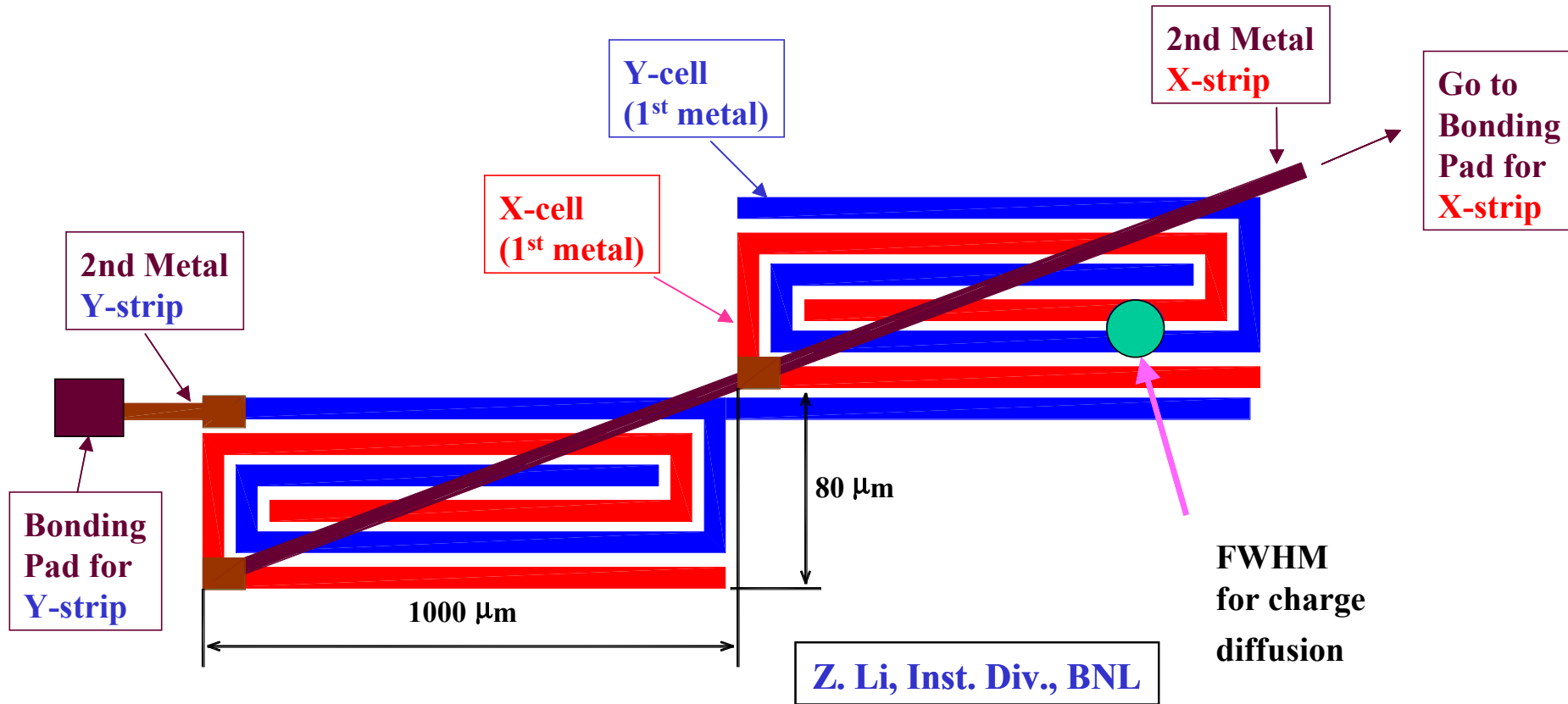
Stereo angle between u and Y strips: 4.6  $^\circ$

MCZ p-type, detector thickness 200  $\mu\text{m}$



# Schematic of the Prototype Stripixel Detector

## PHENIX Upgrade



Pixel pitch : 1000  $\mu\text{m}$  in **X**, and 80  $\mu\text{m}$  in **Y**

Pixel arrays: 30x384

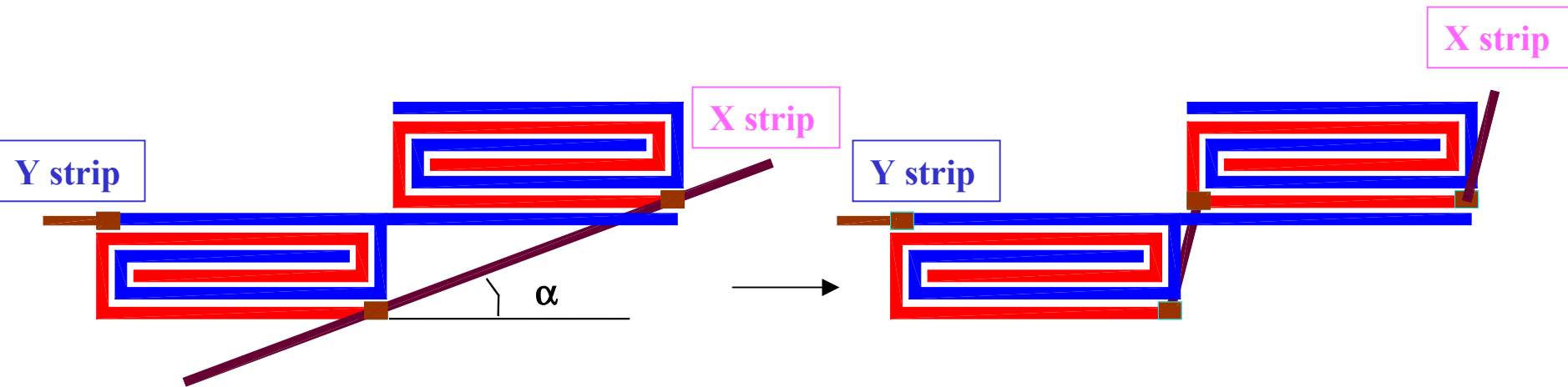
4.6° stereo angle between **X** and **Y** strips

$$\sigma_y = \sim 25 \mu\text{m}$$

# Connection schemes for ISD:

The same stereo angle  $\alpha$

Shorter X strip line (by a factor of  $\sin \alpha$ ) ----- good for small  $\alpha$

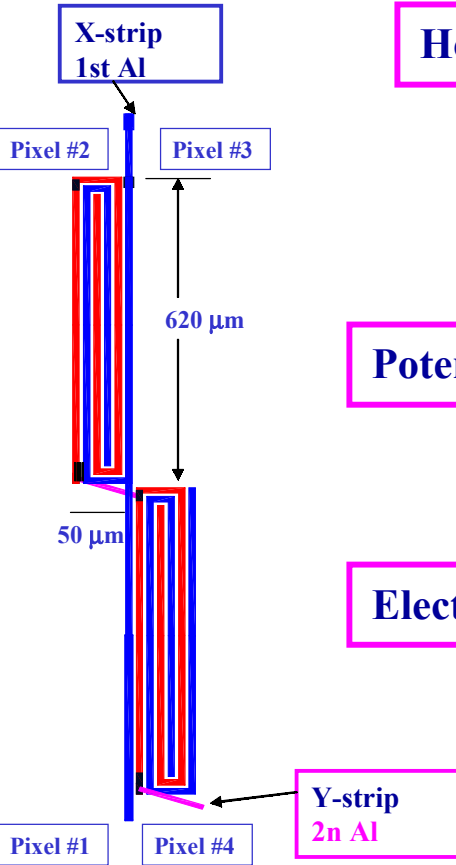


“*Pixel*” = interleaved cell

“*Strip*” = a string of interleaved cells

# US ATLAS Upgrade

Electric simulation on the  
Novel **n on p** and **n on n**  
2d-sensitive Si **Stripixel**  
detectors on **MCZ** wafers  
For US-ATLAS Upgrade  
After  $2 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$   
radiation

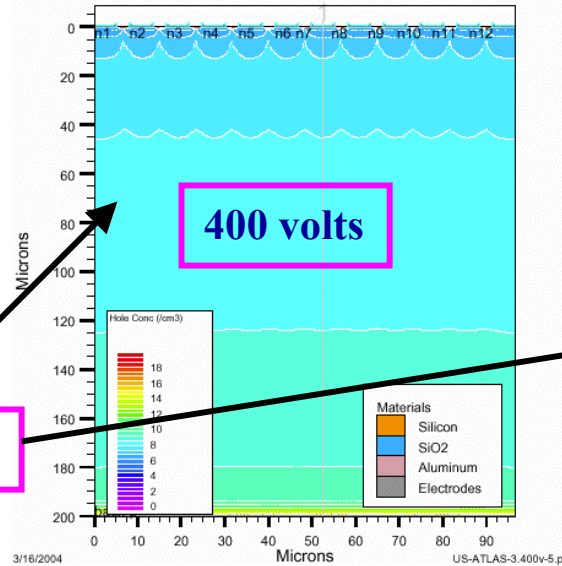


Hole concentration

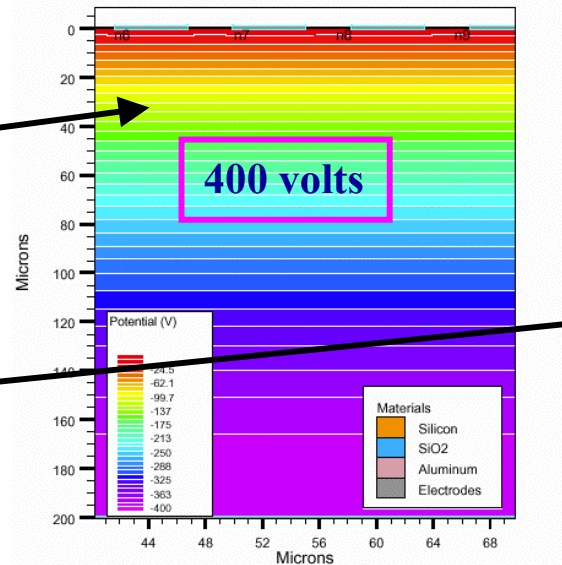
Potential profile

Electric field

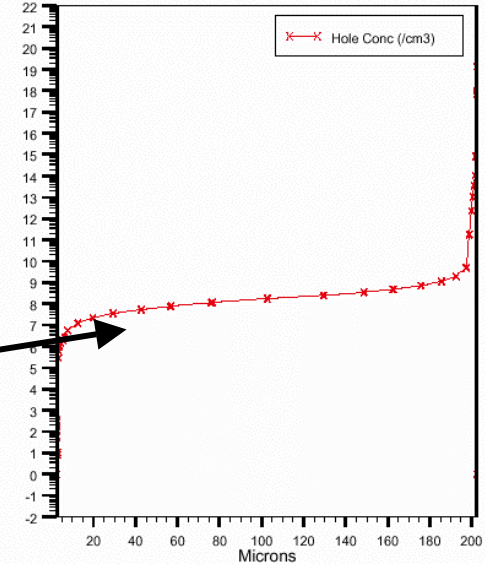
US-ATLAS n+/p/p+ MCZ Si Stripixel detector, 50  $\mu\text{m}$  pitch x and u strips  
50 $\mu\text{m}$ x620 $\mu\text{m}$  pixel, 8.33 interleaving pitch,  $2 \times 10^{15} \text{ n}_{\text{eq}}$  (neff= $1.35 \times 10^{13}/\text{cm}^3$ )



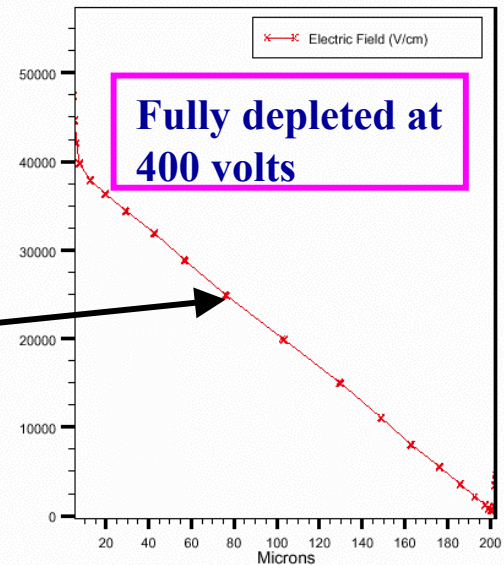
US-ATLAS n+/p/p+ MCZ Si Stripixel detector, 50  $\mu\text{m}$  pitch x and u strips  
50 $\mu\text{m}$ x620 $\mu\text{m}$  pixel, 8.33 interleaving pitch,  $2 \times 10^{15} \text{ n}_{\text{eq}}$  (neff= $1.35 \times 10^{13}/\text{cm}^3$ )



Section 1 from =US-ATLAS-3.400v.std  
(52.5, -2.57) to (52.5, 200)

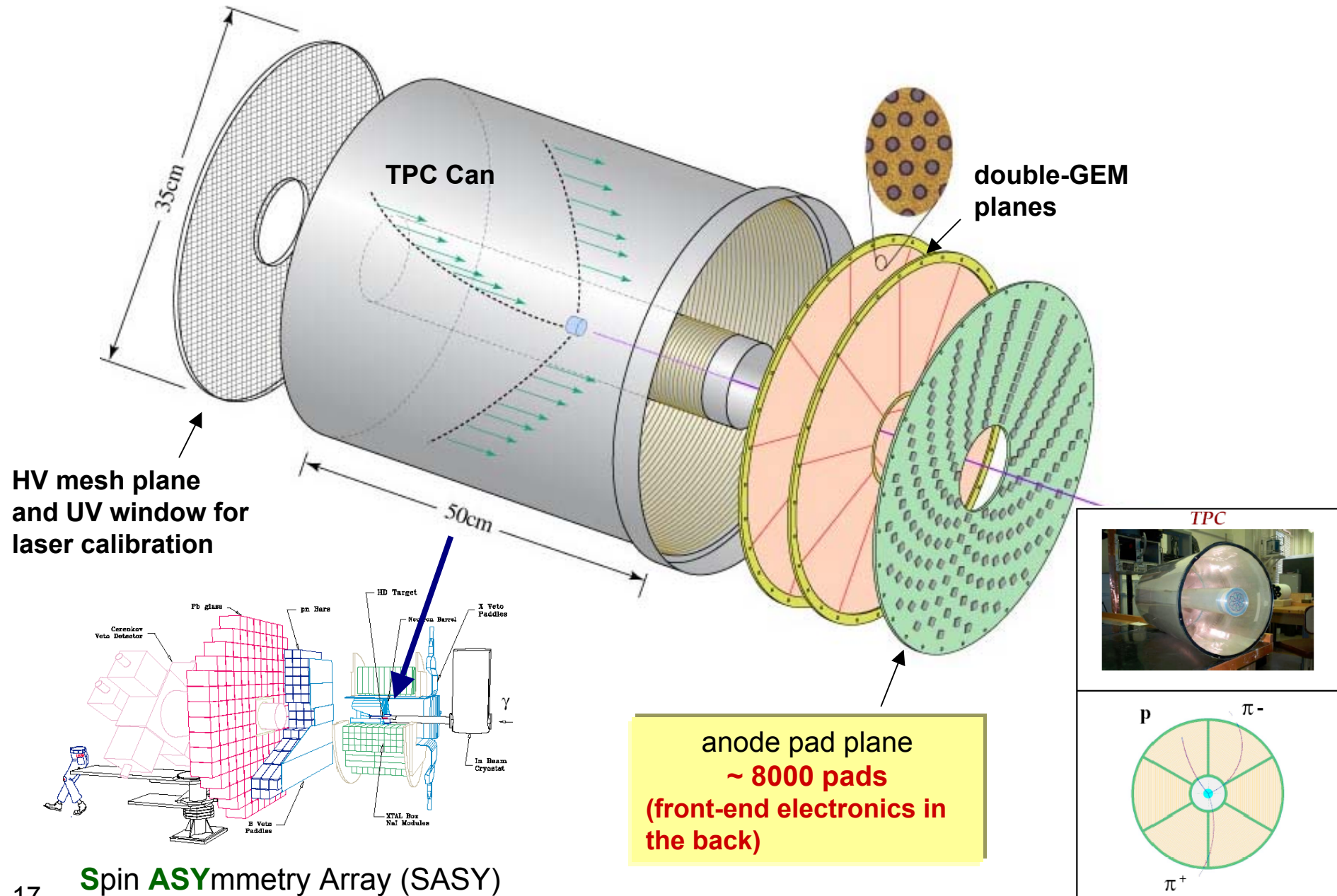


Section 1 from =US-ATLAS-3.400v.std  
(52.5, -2.57) to (52.5, 200)

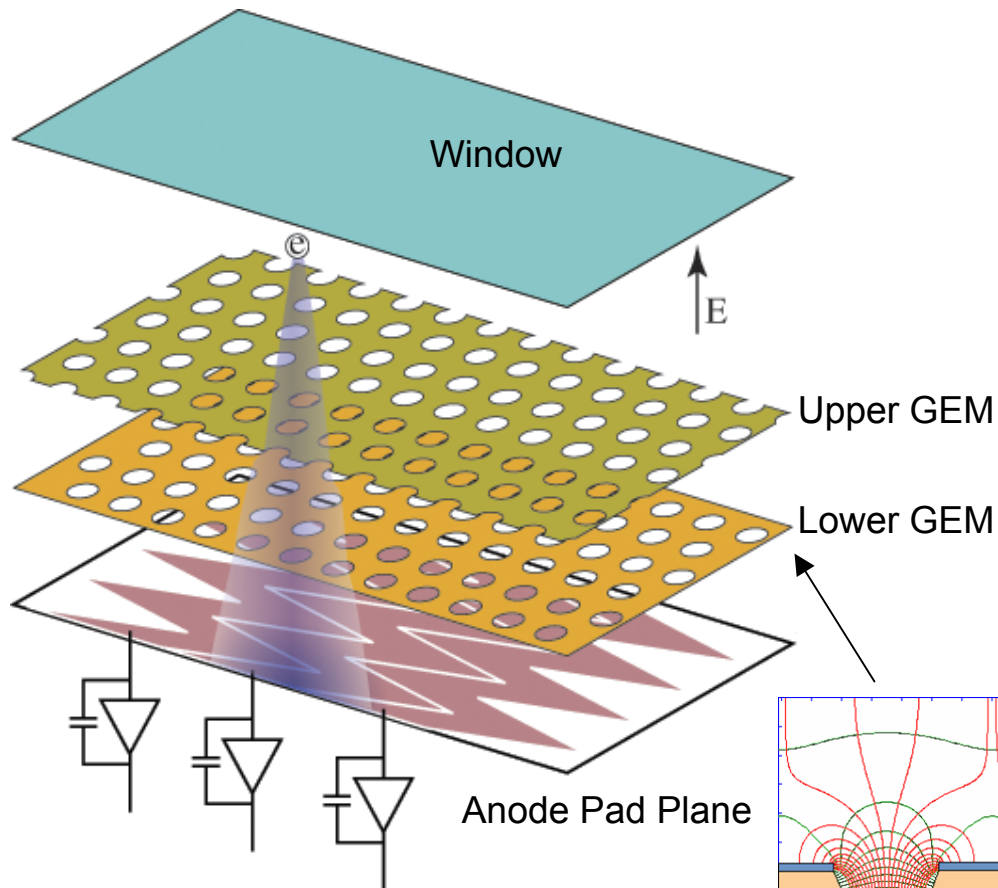


# **Gas and liquid detector research**

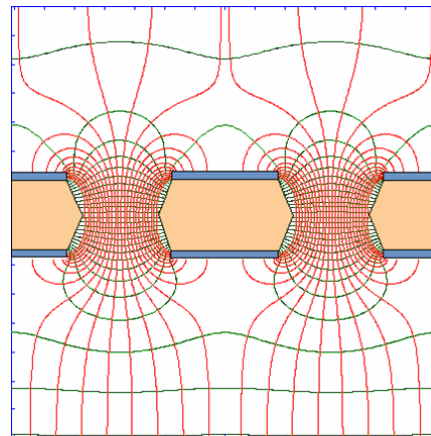
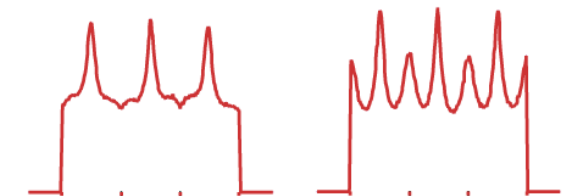
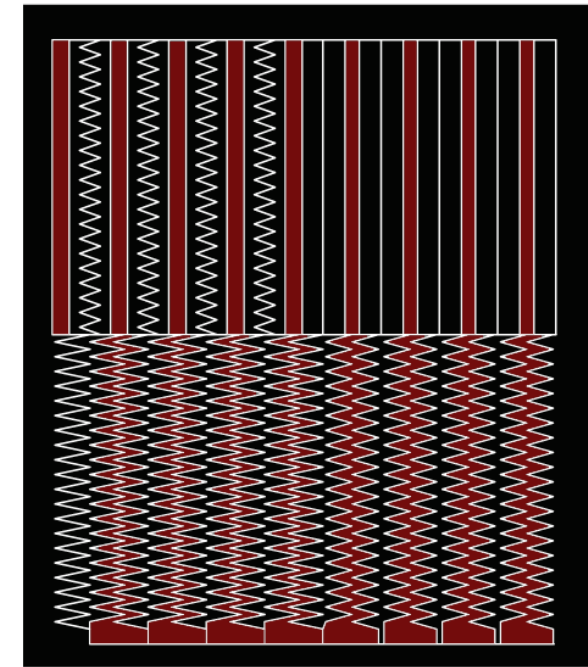
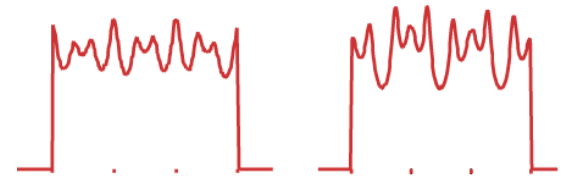
# Time Projection Chamber (TPC) for Laser Electron Gamma Source



# Interpolating Pad Readout for GEM (Gas Electron Multiplier)

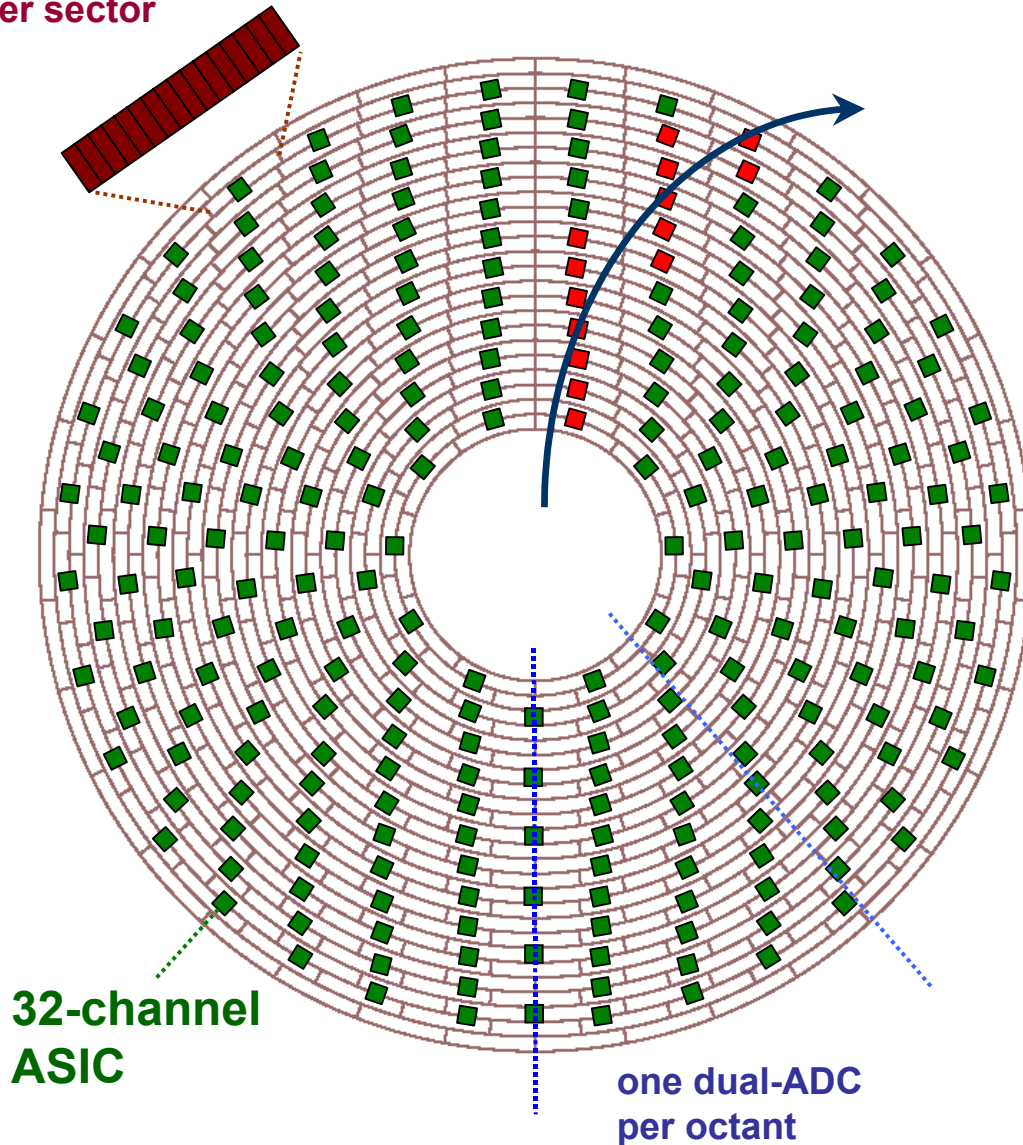


<100 $\mu$ m rms  
position  
resolution  
with 2mm pad  
pitch



## Readout Electronics

16 pads  $2 \times 5 \text{ mm}^2$   
per sector



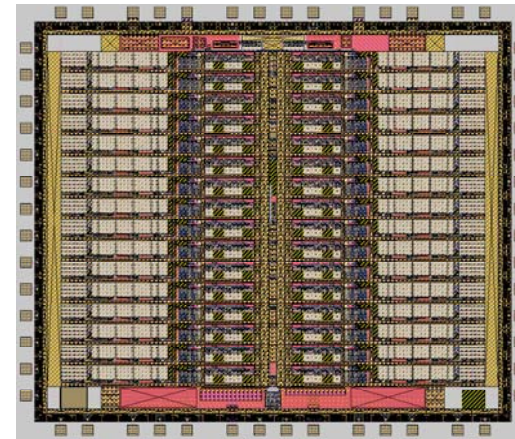
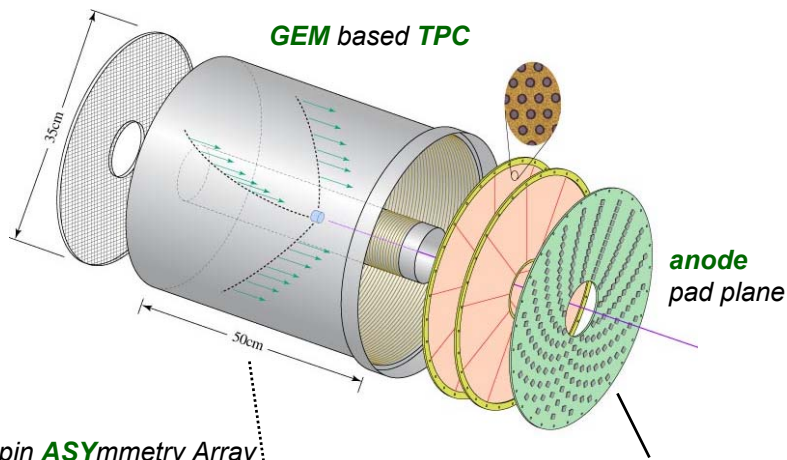
### Tracking Measurement

- Energy - triggered pad (xy)
- Energy - neighbor pads (xy)
- Timing (z)

### Specifications

- ENC < 500 e<sup>-</sup> rms
- Timing < 20ns
- Preamplifier/shaper/BLH
- Peak-detector
- Timing-detector (TAC)
- On-chip buffers
- Neighbor channel/chip enable
- Adjustable gain  $\approx 17\text{-}32 \text{ mV/fC}$
- Channel masking
- Calibration
- Token/flag readout

# Application Specific Integrated Circuit for LEGS Time Projection Chamber

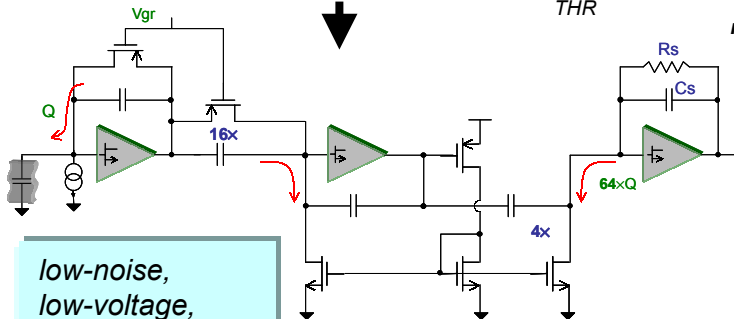
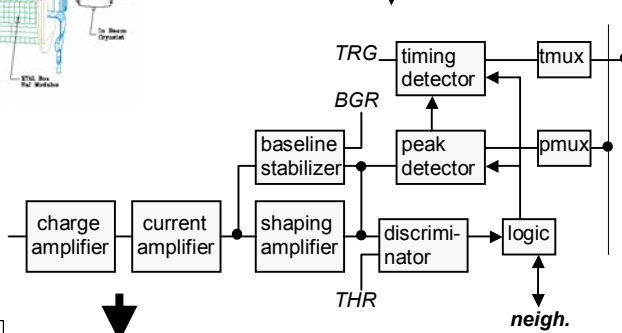
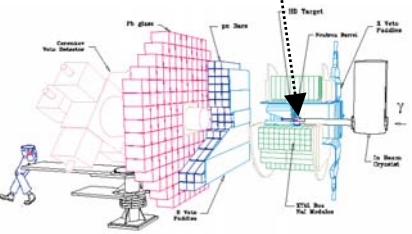


- 32-channel ASIC
- 1.2mW / channel
- peak/timing detection
- 250e- energy resolution
- 2ns timing resolution
- neighbor logic
- peak/timing detection
- sparsified readout

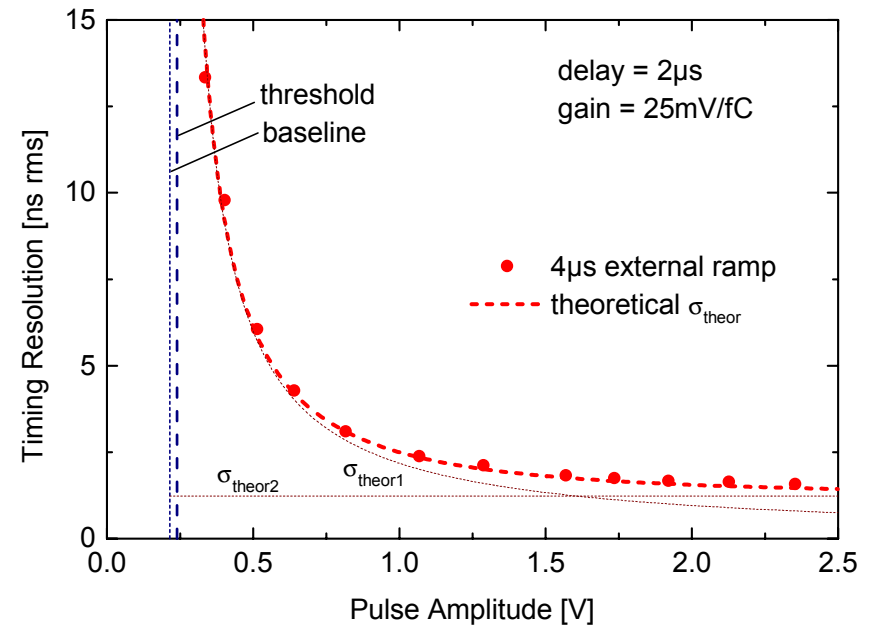
0.25μm CMOS, 3.6x3.1mm<sup>2</sup>

8000 front-end channels

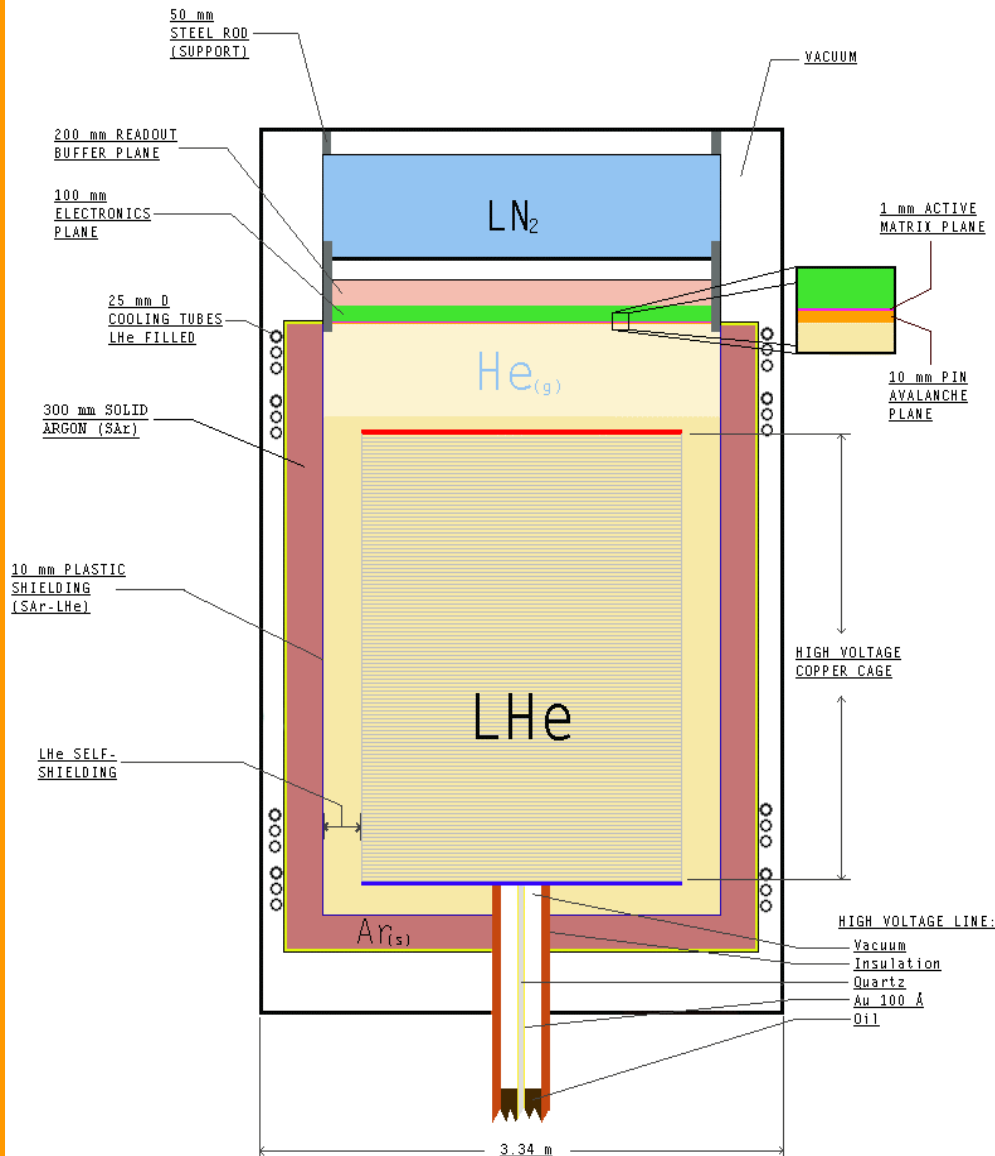
Spin ASYmmetry Array



low-noise,  
low-voltage,  
continuous reset



# Neutrino detector based on tracking in liquid He



## Applications:

Low Energy Solar pp Reaction Neutrinos,  $E < 423$  keV

Astrophysical Neutrinos

Geophysical Neutrinos

Reactor Neutrinos and their Magnetic Moment

High Energy Clean Neutrino Events

Identification of Heavy Flavors in Neutrino Interactions

New Particle Search (SUSY – type)

## R&D:

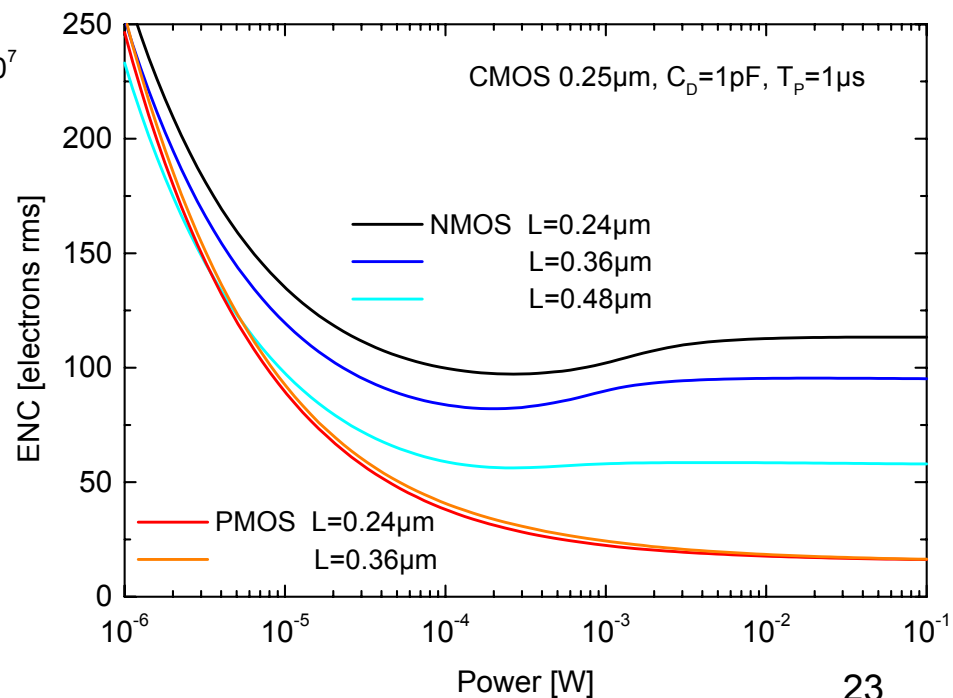
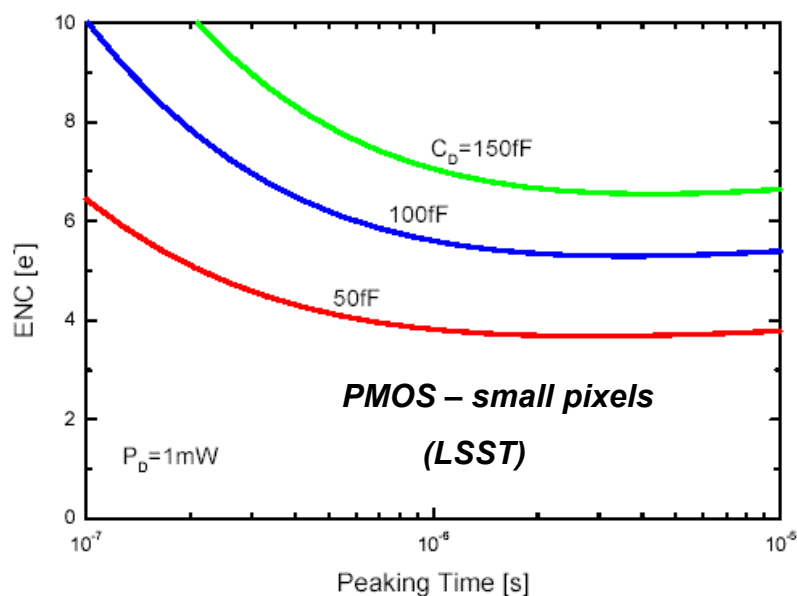
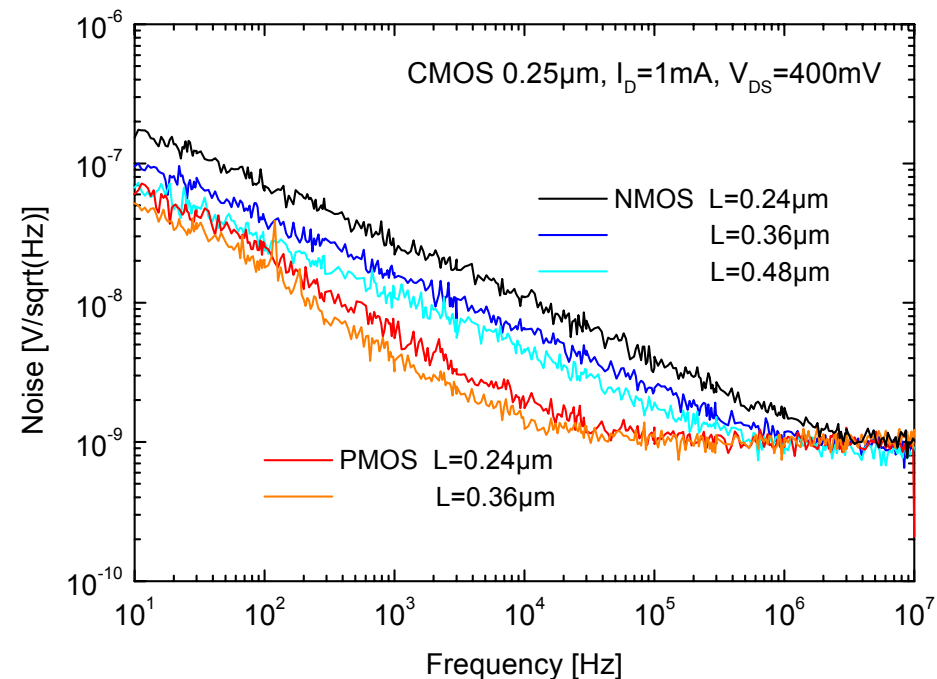
readout electronics (CMOS) at low temperatures; electron amplification;

.....

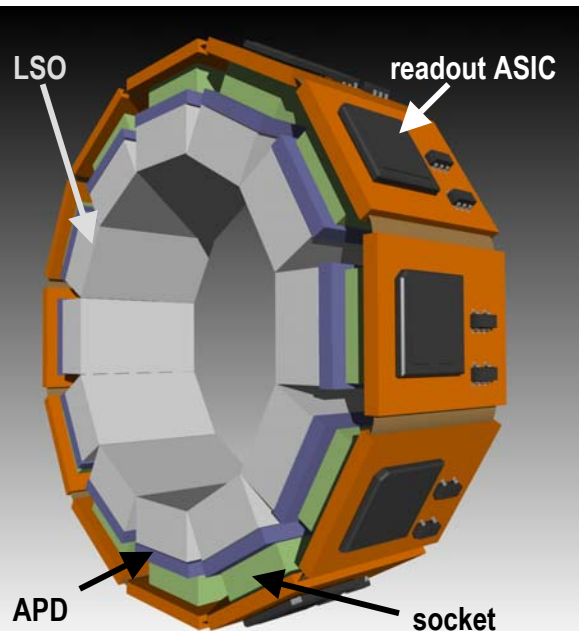
# **Microelectronics**

# Characterization of CMOS Technologies for Low-noise Low-power Front-ends

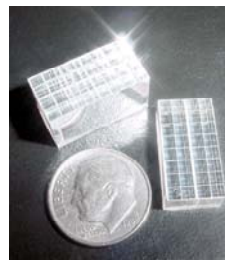
- n- vs p-channel
- channel length:  $L$



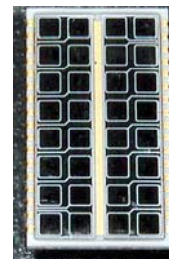
# Electronics for a mobile, miniature animal PET tomograph



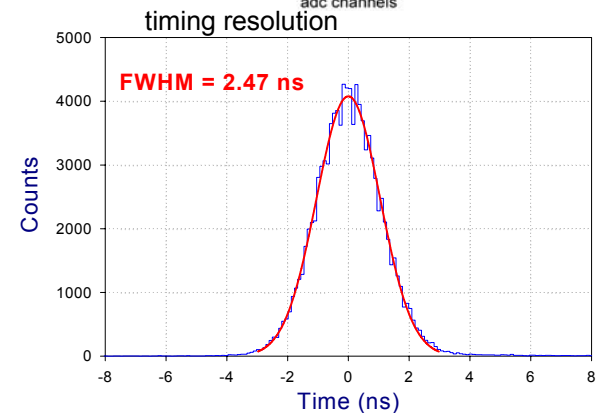
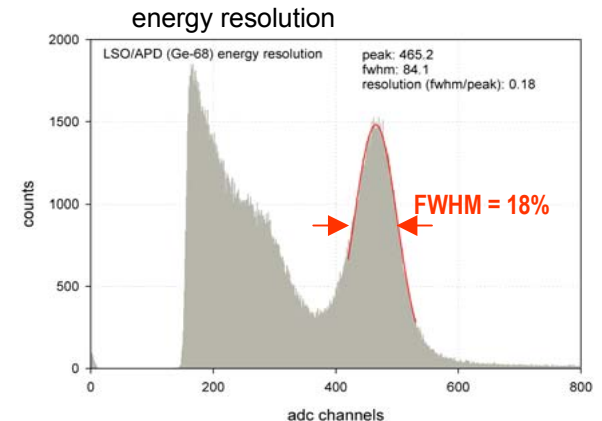
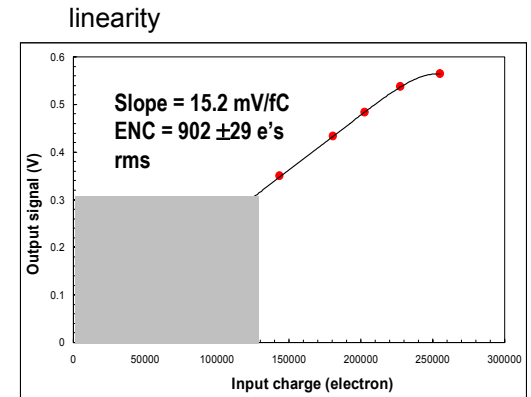
- 0.18  $\mu\text{m}$  CMOS
- 1.5 mW/channel
- 32 channel ASIC
- Preamplifier + shaper + timing discriminator
- address encoding
- serialized output



LSO scintillator



APD array



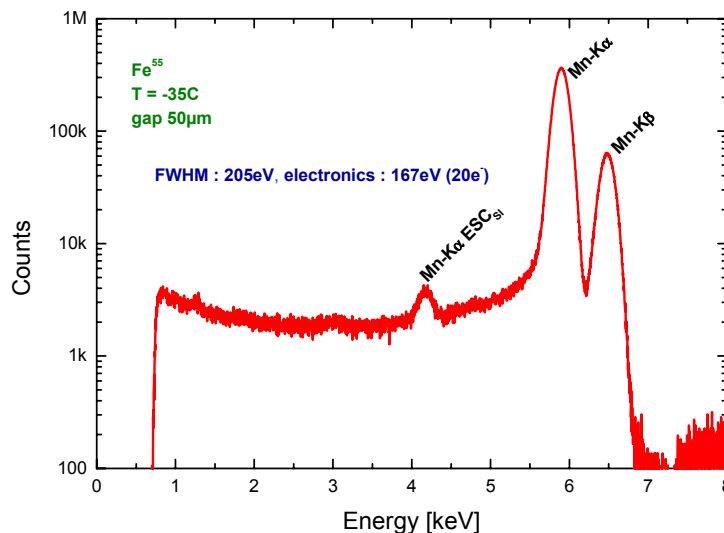
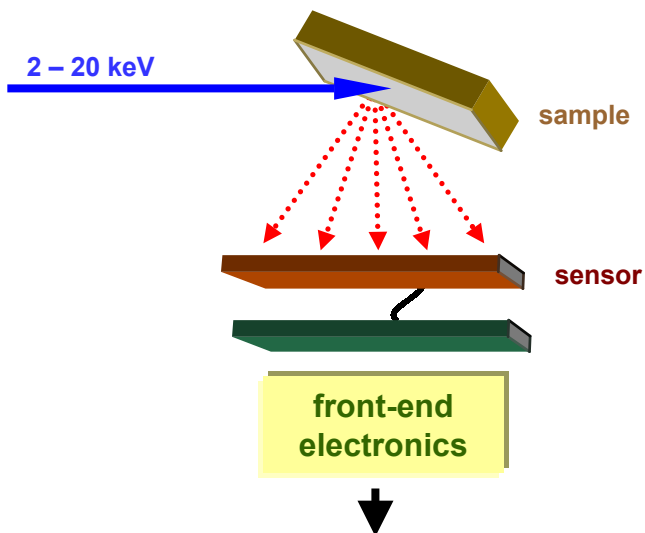
ASIC preamplifier with CFD vs. BaF<sub>2</sub>/PMT



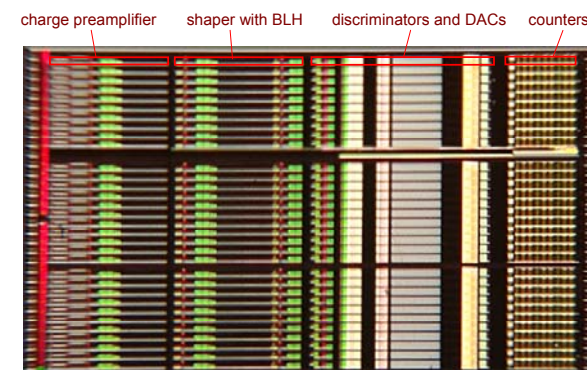
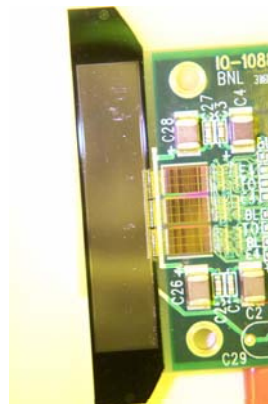
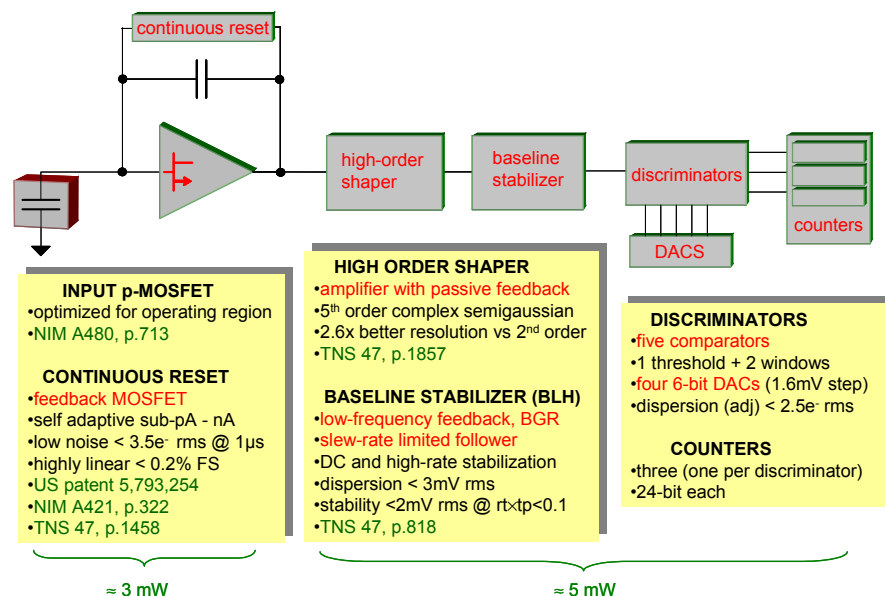
Mockup of the portable ring on the head of a rat

# Application Specific Integrated Circuit for NSLS Experiments

## Fluorescence EXAFS Spectroscopy

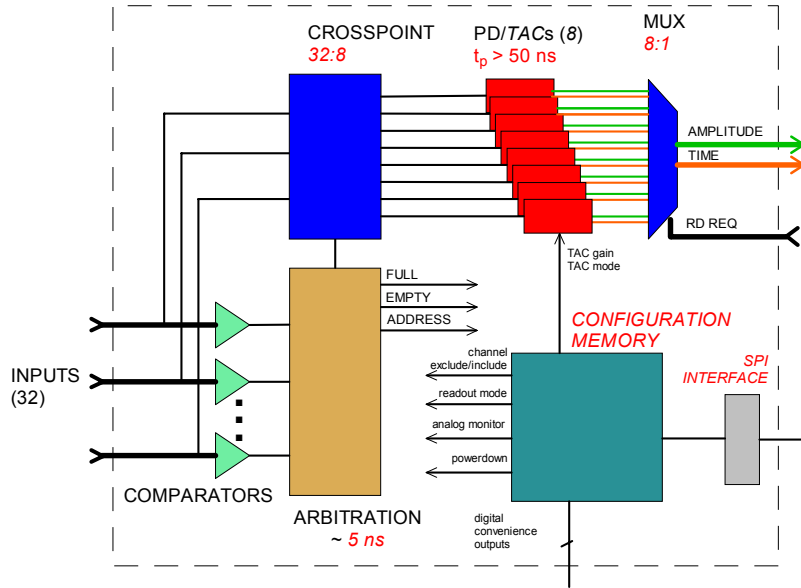


- 32-channel ASIC
- 8mW / channel
- 180,000 MOSFETs
- FWHM 170eV
- serial interface

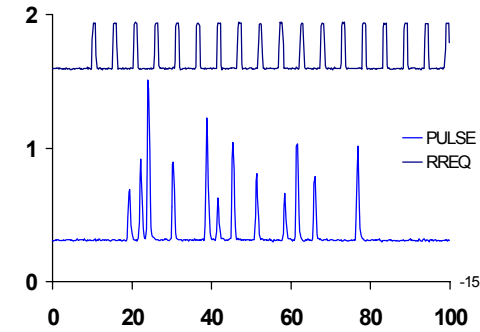


0.35μm CMOS, 3.6x6.3mm<sup>2</sup>

# Amplitude/Time Measurement ASIC with Derandomization

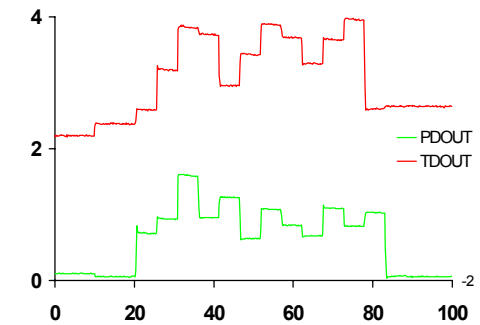


- high-accuracy two-phase peak detector
- < 2mW / channel



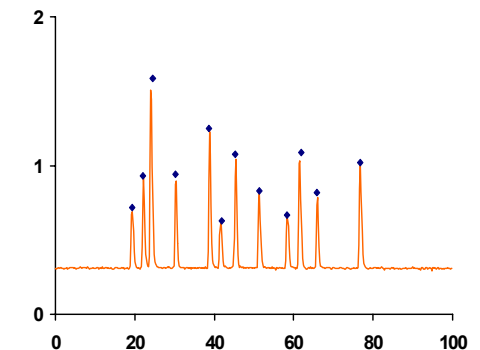
ADC request

sensor

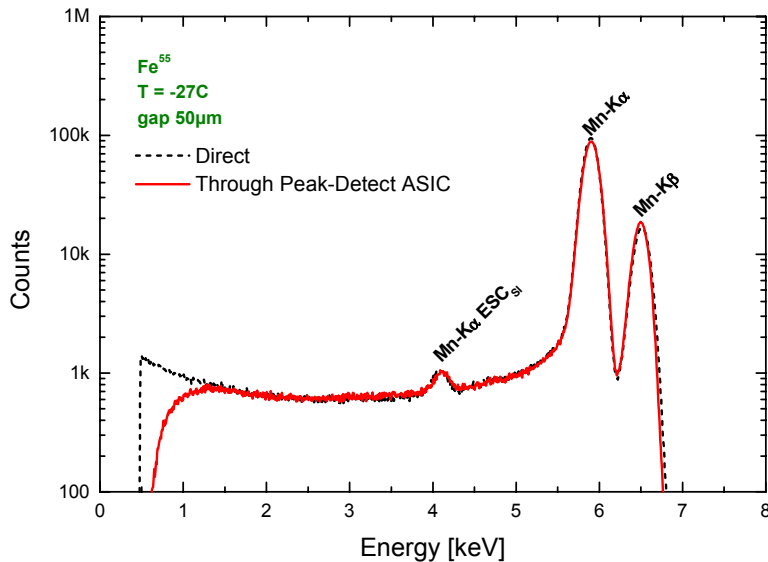


time output

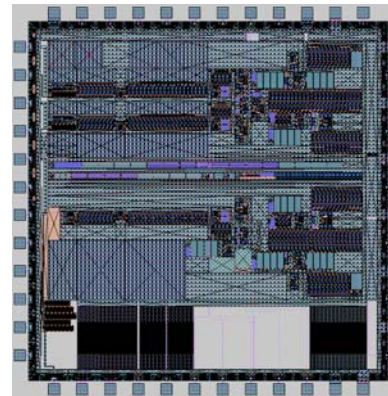
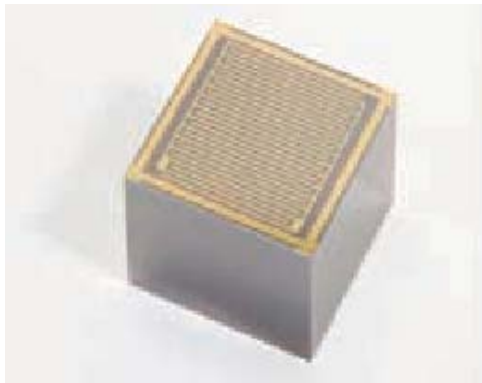
amplitude output



reconstructed signal

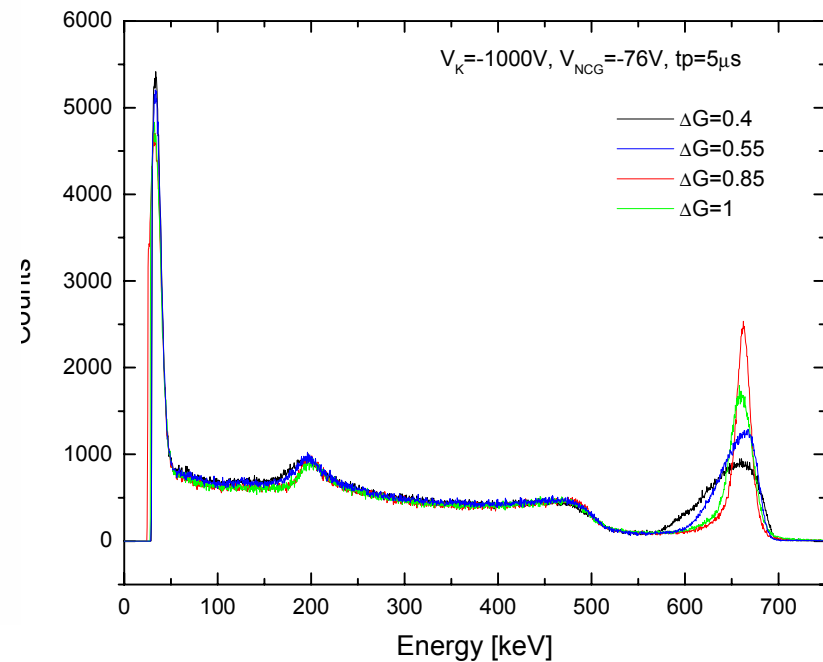
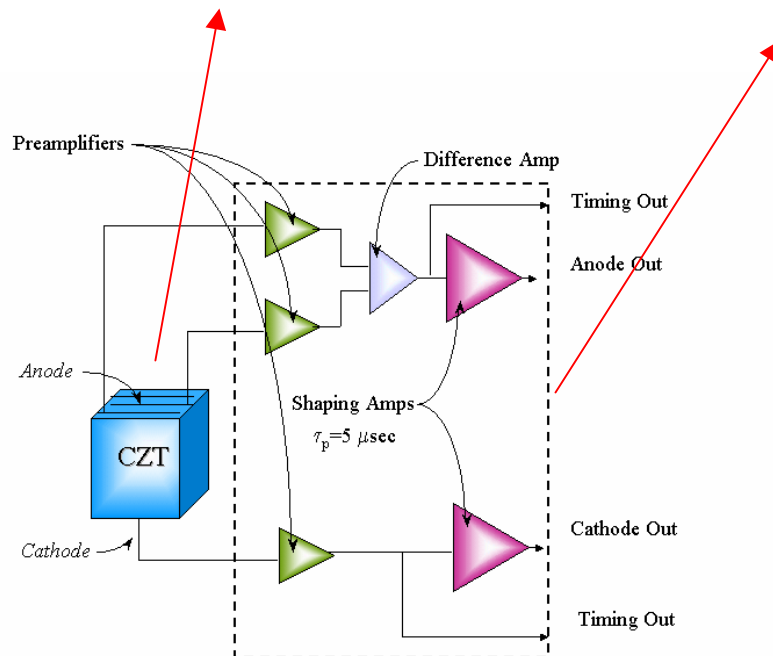


# Application Specific Integrated Circuit for Coplanar Grid CdZnTe Detector



0.25 $\mu$ m CMOS, 3.1x3.1mm<sup>2</sup>

- 2 anode channels
- difference amplifier
- cathode channel
- high-order filter
- timing



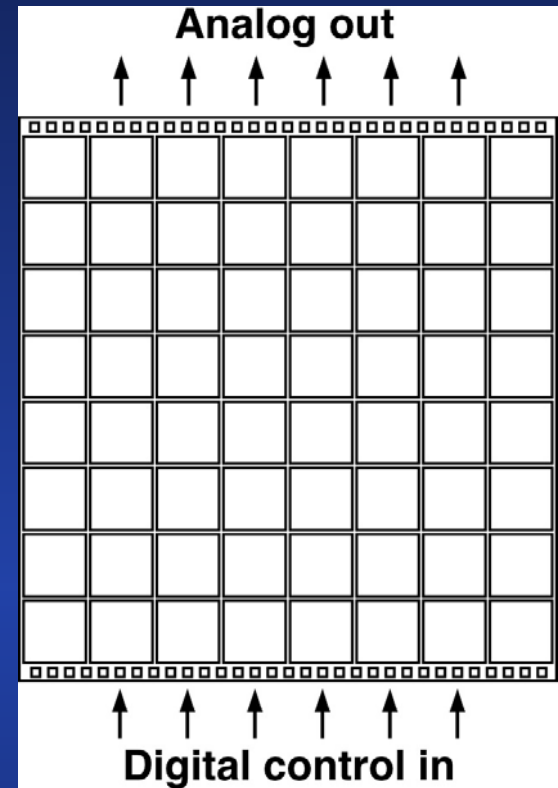
# LSST

# LSST Detector Challenge

- The focal plane array will have about ***an order of magnitude larger number of pixels*** ( ~2.8 gigapixels) than the largest arrays realized so far or being built.
- The effective pixel readout speed will have to be about ***two orders of magnitude higher*** than in previous telescopes in order to achieve a readout time for the telescope of ~ 2 seconds.
- The silicon detectors will have an ***active region ~100-250  $\mu\text{m}$  thick*** to provide sufficiently high quantum efficiency at ~1000 nm, and they will have to be fully depleted so that the signal charge is collected with minimum diffusion as needed to achieve a narrow ***point spread function,  $<10\mu\text{m}$*** .

# Highly Segmented CCDs for LSST: *An Example*

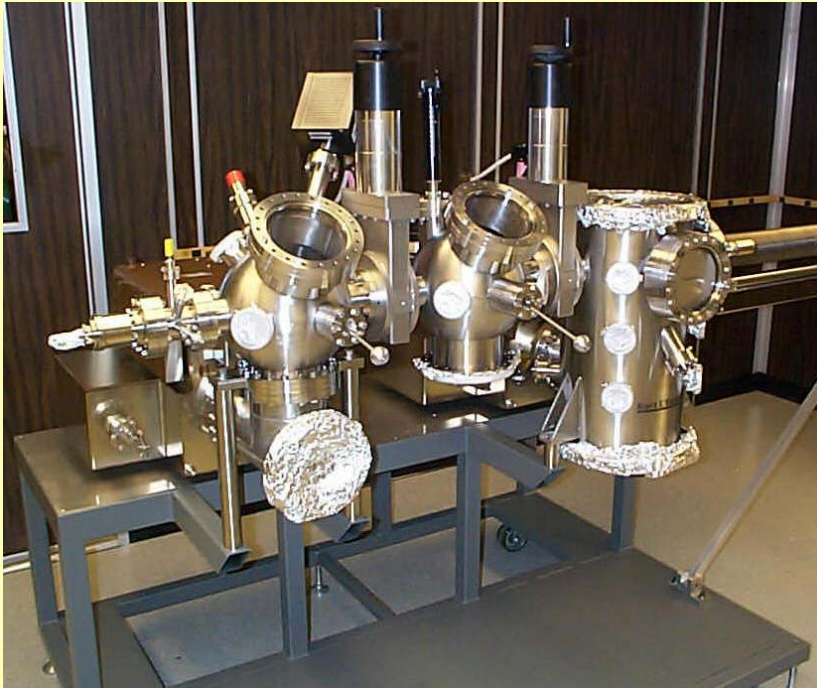
- High performance “scientific” CCDs have 1 to 4 signal ports, resulting in readout times of tens of seconds for larger CCDs.
- Assume a  $2k \times 2k = 4$  Mpixels CCD divided into  $8 \times 8$  segments with 8 signal ports. With a clock rate of  $4 \mu\text{s}/\text{pixel}$  (250 kHz), to achieve  $<5$  rms e noise, it takes 2s to read out.
- The charge integrated in pixels in each CCD is read out by an 8-channel ASIC.
- An LSST focal plane array with  $\sim 700$  CCDs+ASICs would be read out in parallel via 5600 signal channels. After digitization the data will be transferred from the camera at a much higher rate via a small number of data links.
- By segmentation and the use of ASICs a short overall readout time is achieved, while charge signals are processed at a low CCD clock rate.
- Segmentation confines the effect of defects in the CCD and of blooming.



# **Lasers and Optics**

# Multialkali Photocathode Development (CAD, IO)

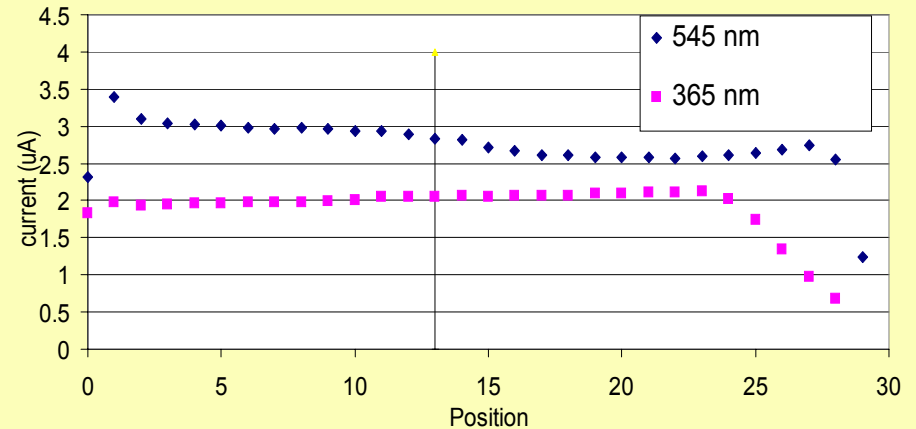
## A multialkali cathode deposition and testing system



### GOALS:

- ELECTRON BEAM PARAMETERS:  
CHARGE 10 nC, PRF 10 MHz,  
AVERAGE CURRENT 100 mA
- QUANTUM EFFICIENCY: FEW % FOR  
VISIBLE PHOTONS
- LIFETIME: >8 HRS AT A VACUUM OF  
 $1 \times 10^{-9}$  TORR

Emission Uniformity Deposition 7 CsKSb



### RESULTS SO FAR:

QE UP TO 3% AT 545 NM

LIFE TIME > WEEKS AT LOW  $10^{-9}$  TORR

INCREASED QE AT 365 NM

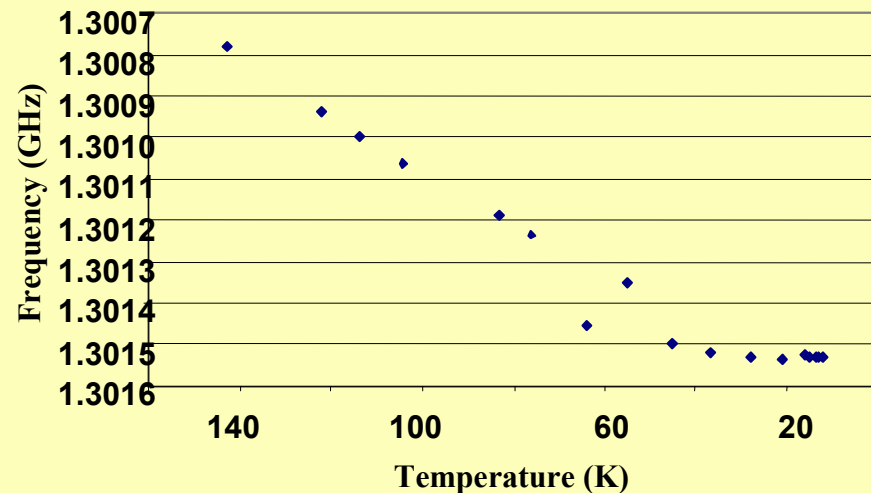
UNIFORM EMISSION AT 545 AND 365  
NM

CURRENT DENSITY COMPARABLE TO  
RHIC II (**e-cooling**) REQUIREMENT,  
FEW DAYS OF LIFE TIME

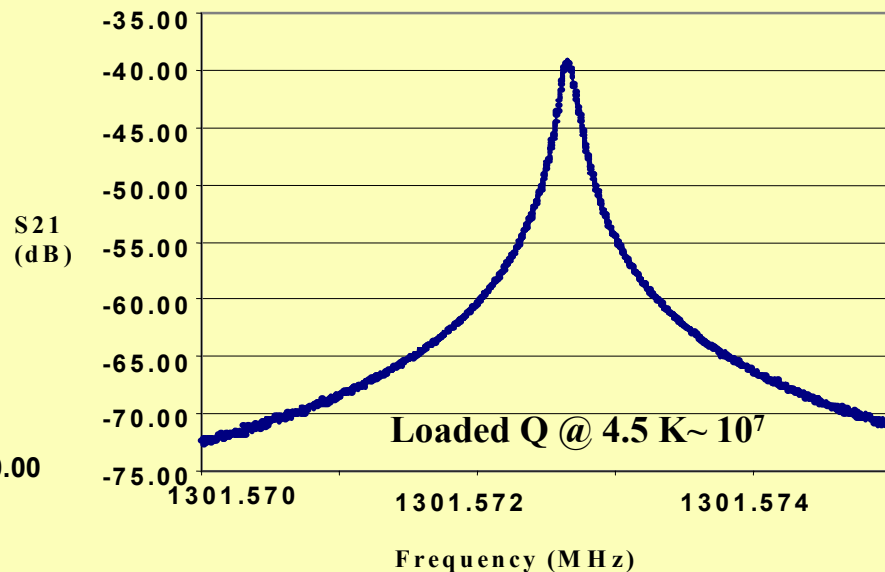
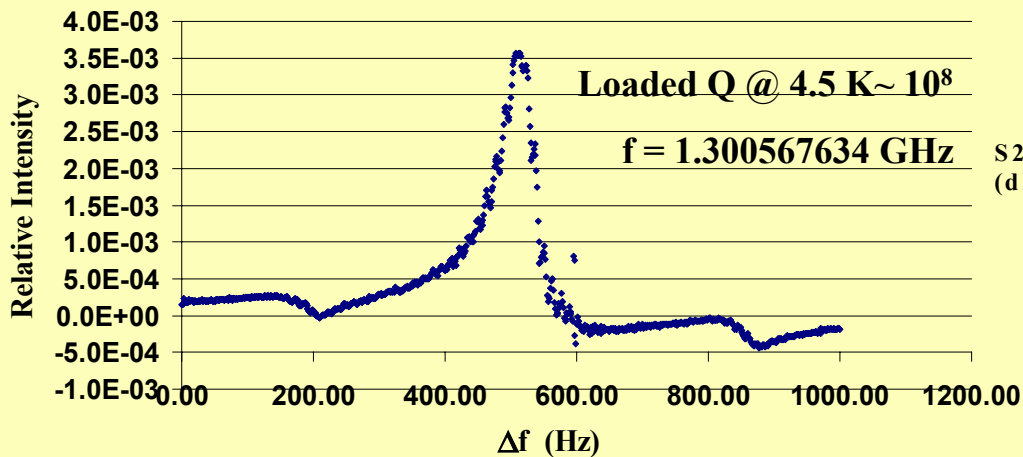
# All Nb Superconducting Photoinjector (CAD, IO, AES)



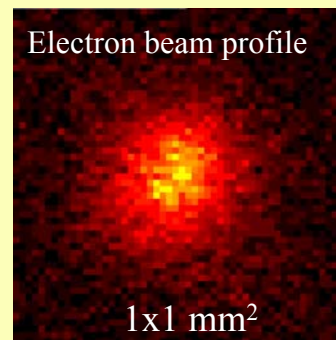
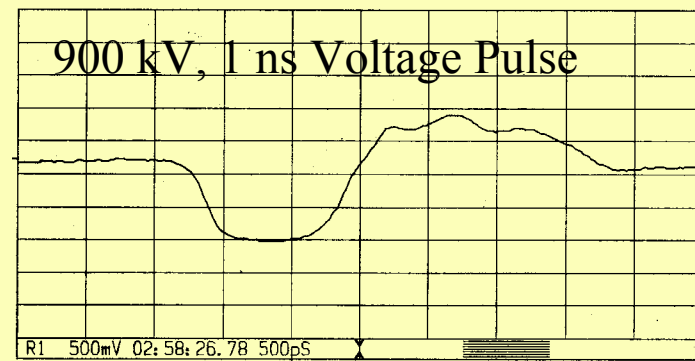
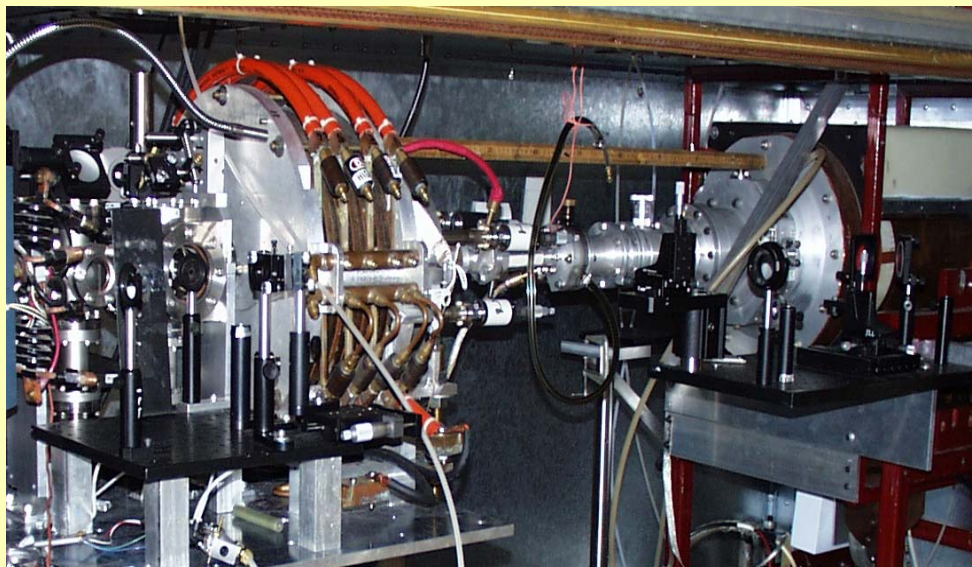
Cavity Performance Before BCP



Nb Cavity Frequency After BCP



# Pulsed Power Injector



Spot size  $\sim 65 \mu\text{m rms}$

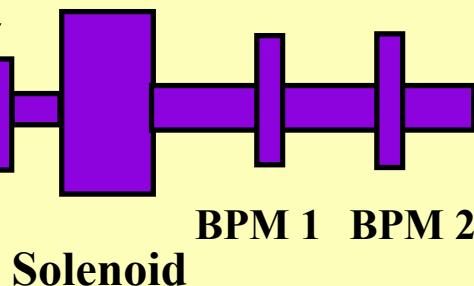
Charge  $\sim 0.4 \text{ pC}$

emittance  $\sim 0.7 \text{ mm mrad}$

**Ti:Sapphire laser**  
266 nm, 60  $\mu\text{J}$ , 300 fs  
To photocathode

**Excimer laser**  
248 nm, 250 mJ, 10 ns  
To laser triggered spark gap

**Pulse Generator**  
1 MV, 1 ns



## System Capabilities

Voltage range: 150 - 900 kV, 1 ns FWHM

Cathode laser: 60  $\mu\text{J}$ , 300 fs FWHM, 266nm

System timing jitter:  $< 1 \text{ ns}$

Accelerating gradient:  $> 1 \text{ GV/m}$

Maximum current density:  $> 100 \text{ kA/cm}^2$

Maximum charge:  $> 60 \text{ pC}$  from 300 fs laser

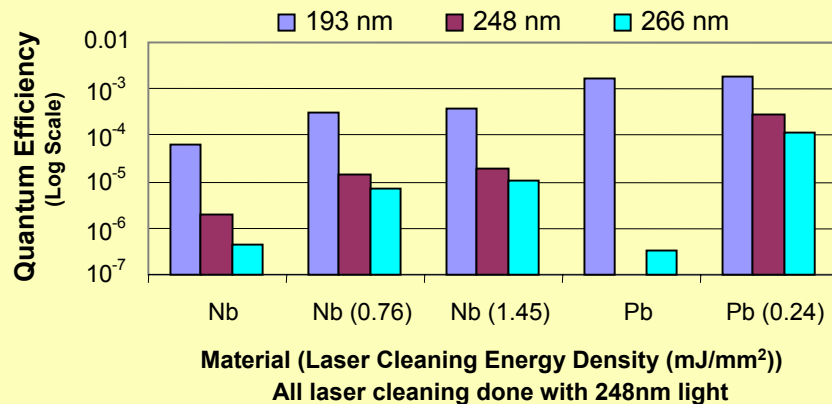
# New direction in laser applications

## ***Superconducting Lead Photoinjector Development***

*To improve the Quantum Efficiency of superconducting photoinjectors. This research may lead to an injector capable of meeting the high average current requirements of tomorrow's LINAC-based Light Sources (up to 1nC bunch charge, 1 mA average current, 1 MHz rep. rate).*

*Preliminary Measurements:*

**Lead has Four to Ten times higher QE than Niobium**

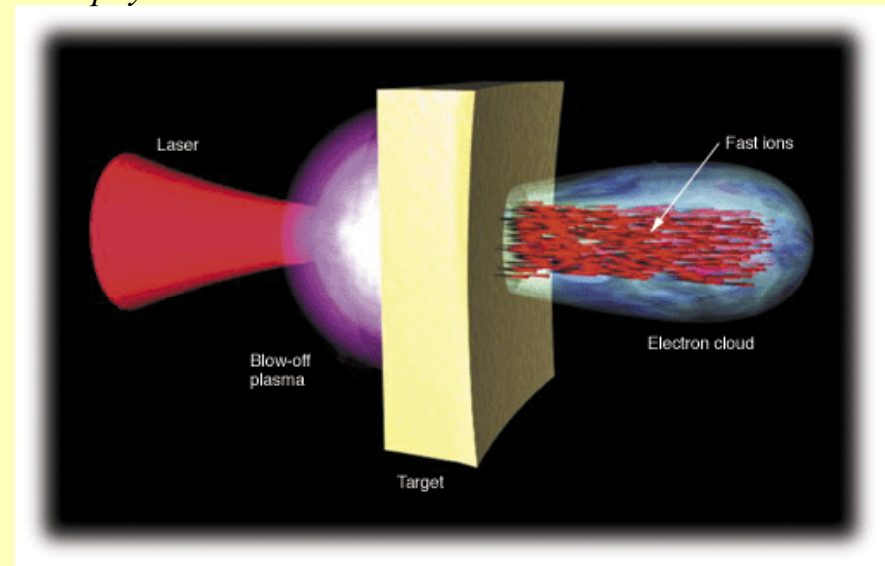


*What we propose:*

***Develop techniques to deposit lead on the cathode region of a niobium superconducting injector. Optimize laser parameters to maximize charge extraction without quenching.***

## ***Electron and X-ray Production by Ultra-intense Laser Interaction with Material***

*To develop a laser-based source capable of efficiently producing multiple types of radiation. Multi-TW laser sources have the potential to provide spatially coherent, femtosecond particle (electron, proton positron, ion) and X-ray beams, revolutionizing fields such as radiography and astrophysics.*

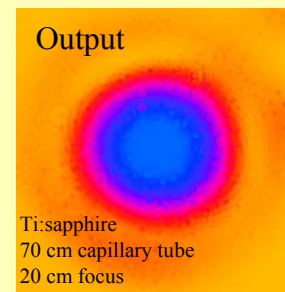
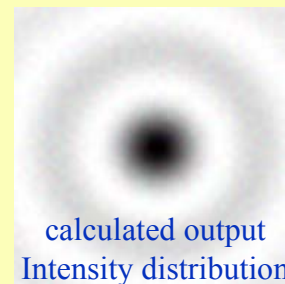
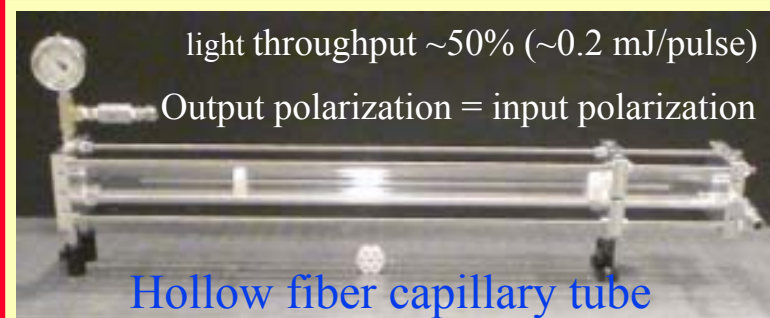
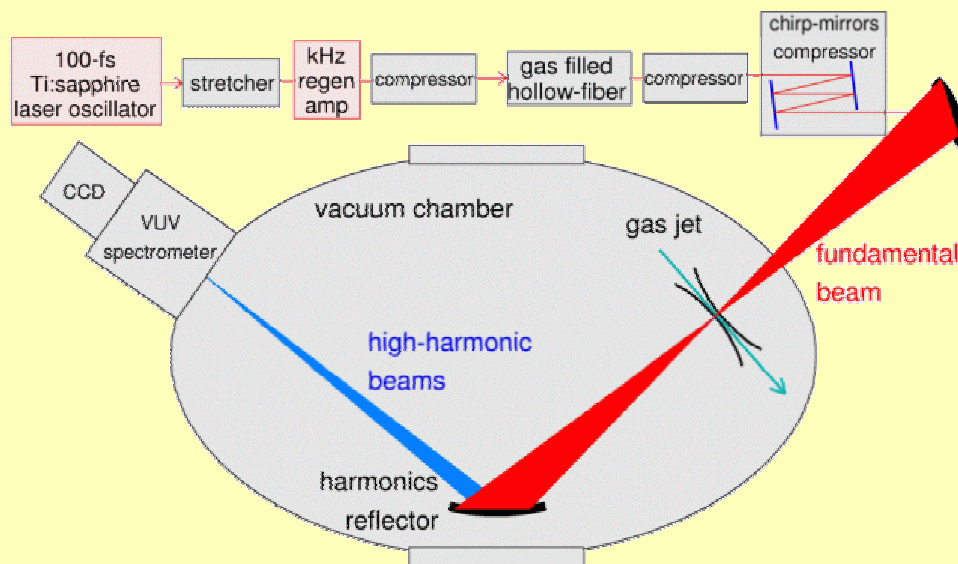


*What we propose:*

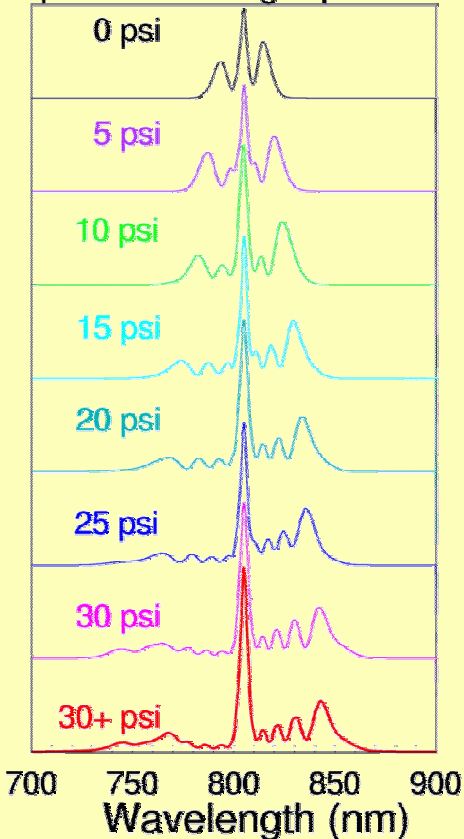
Optimize target and laser pulse parameters to produce characteristic (K- $\alpha$ ) X-rays and energetic electrons. Provide a diverse particle source useful for radiography and detector calibration.

# Generation of Coherent, Femtosecond, High Brightness VUV and X-Ray Beams Using High Order Harmonic Conversion

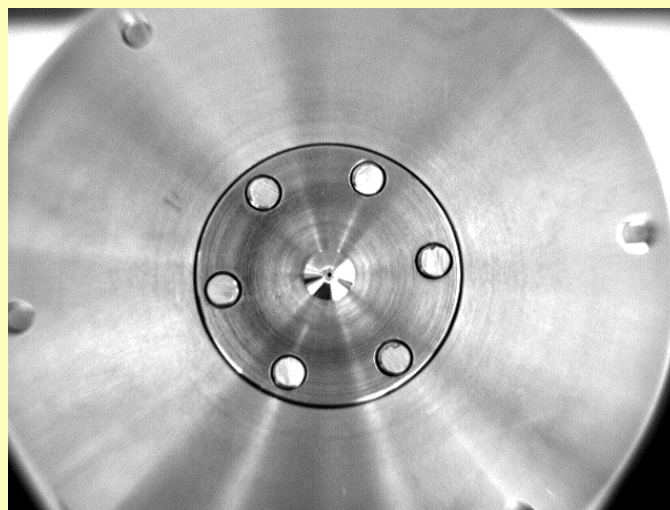
2002 LDRD



spectrum vs. Kr gas pressure



high repetition  
rate gas jet



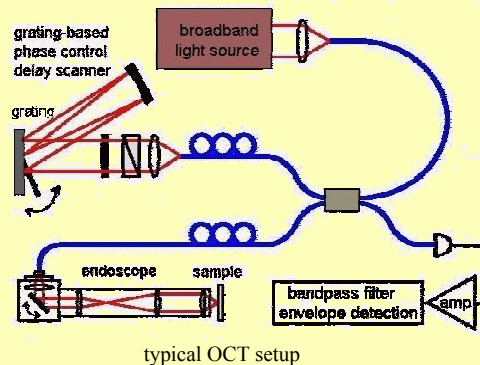
gas jet operation at ambient

## Optical coherent tomographic (OCT) imaging of biological tissues

To develop a noninvasive medical diagnostic tool using non-ionization radiation sources. The program benefits the Life and Physical Science programs to be established at BNL

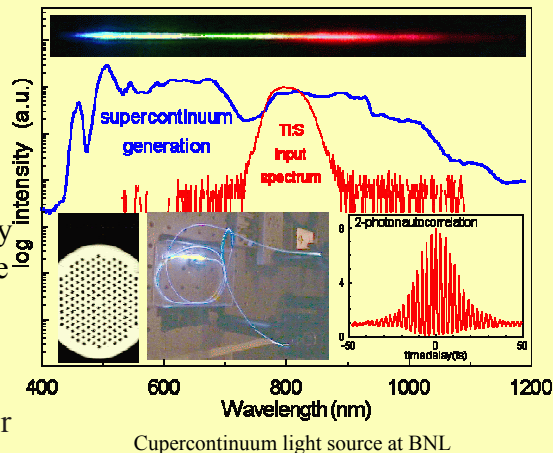
### What we know:

OCT is a non-contact interferometric technique that measures the reflected or back-scattered light from within the subsurface biological tissue. The image resolution improves with larger laser bandwidth



### What we propose:

OCT imaging using supercontinuum light source → highest image resolution. Combine a fluorescence-guided method to substantially enhance the efficiency and the sensitivity for rapid medical diagnosis. The new technique has the potential for the detection of early-stage cancer can be much improved.

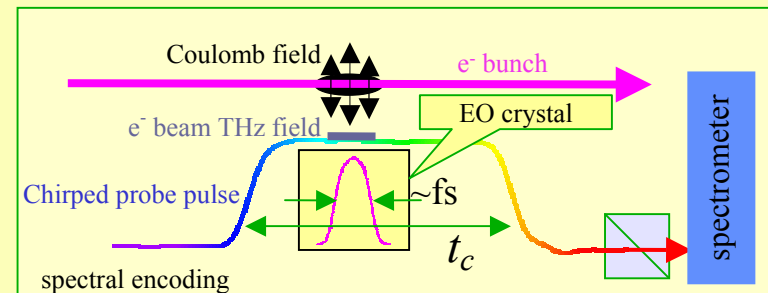


## Characterization of femtosecond electron bunch: cross-correlation technique

The electron bunch lengths continue to drop below the sub-100-femtosecond regime in various accelerator facilities including the SDL and the ATF at BNL, optical pulses of equal duration or shorter are needed to characterize the femtosecond electron bunch

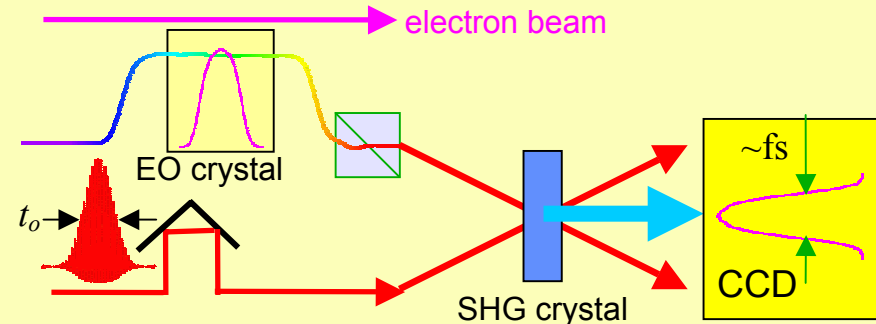
### What we know:

Spectral encoding technique has an **intrinsic time resolution limitation** that is always longer than the duration of the unchirped optical pulse



### What we propose:

Spectral encoding & cross correlation technique to **remove the intrinsic time resolution limitation completely** → measurement of electron bunch length to below 100-femtosecond for the first time.

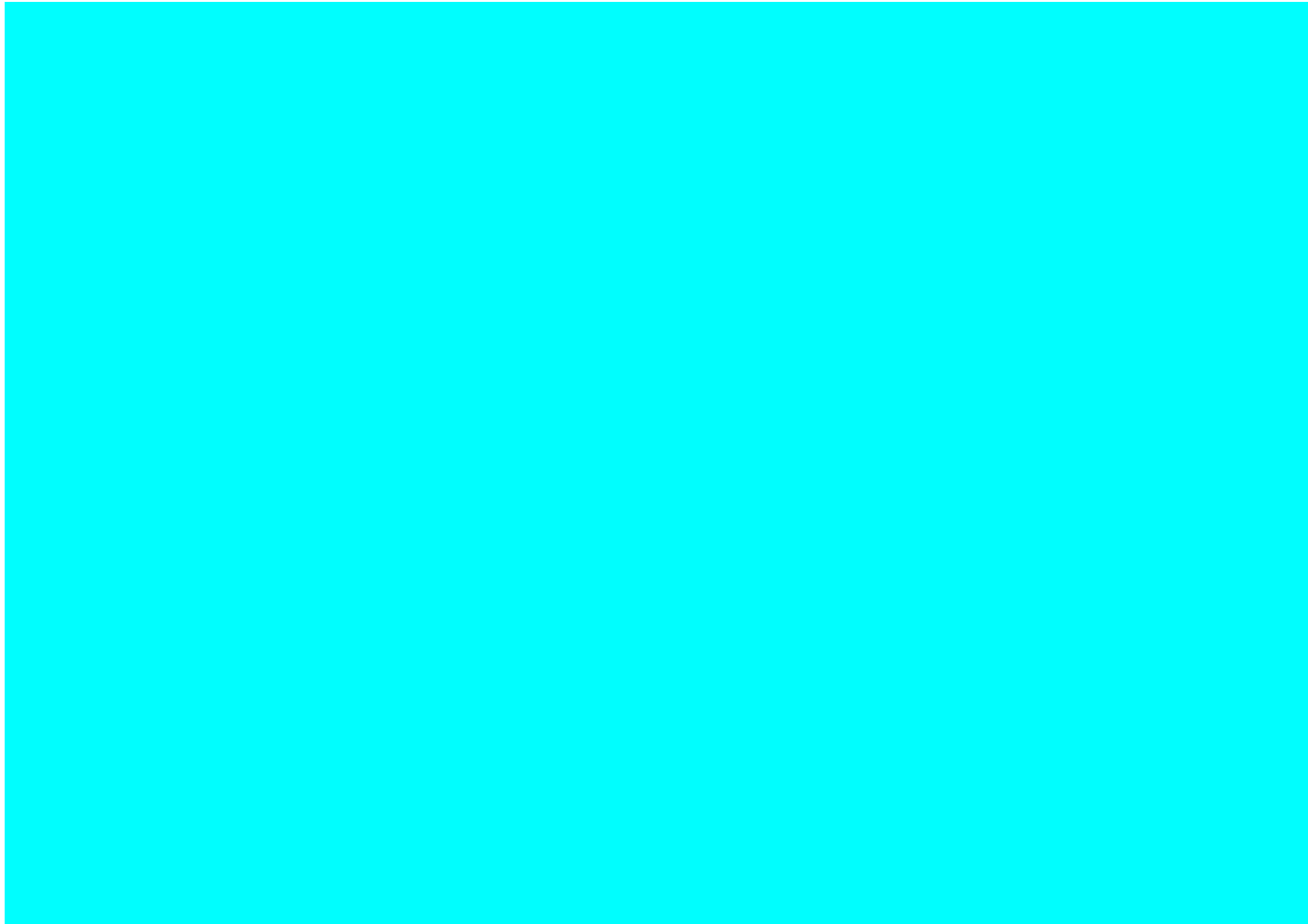


# Optical System Design

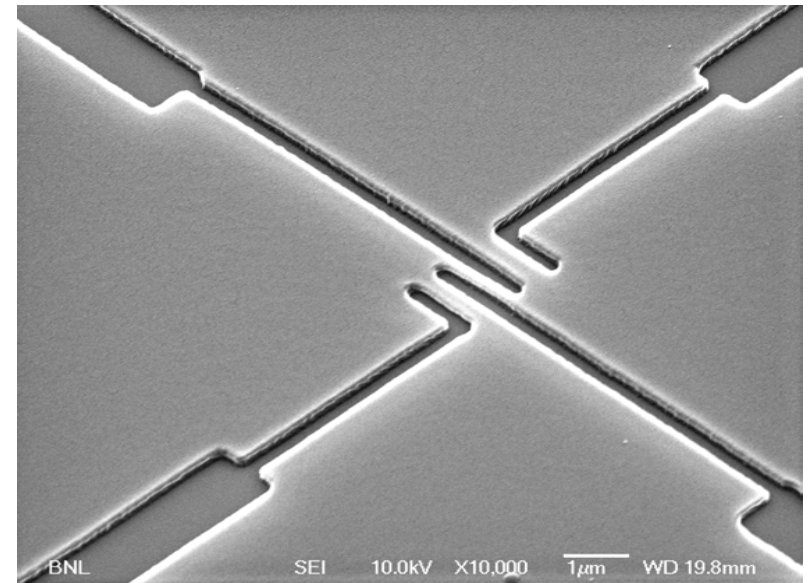
ZEMAX optical design code

OptiCAD optical system analysis code

- M. Diwan, Physics
  - Lens for Cerenkov imager for neutrino detector project
    - Low resolution, underwater, broad wavelength band
    - Large angular acceptance range



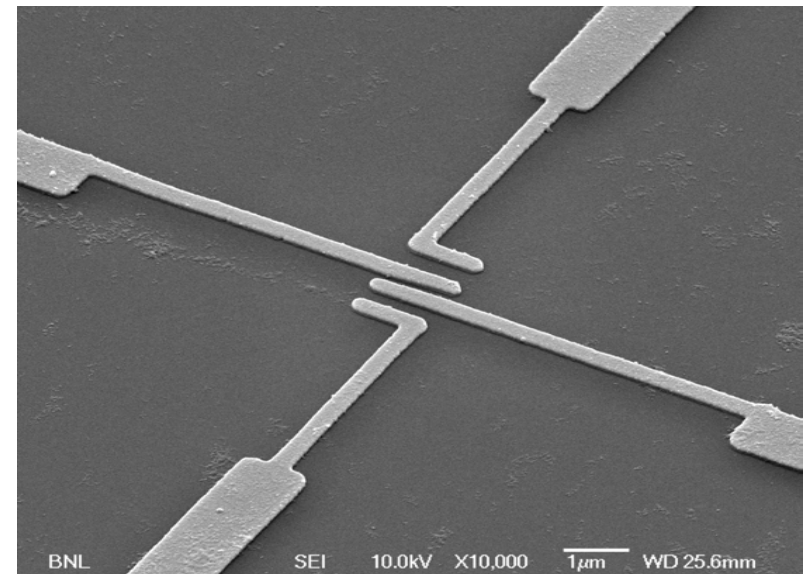
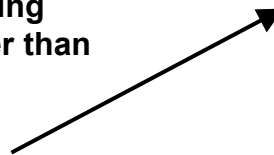
# **Micro/nano Fabrication**



PMMA after nanopatterning in JSM-6500F

Since installation in July 2003, Instrumentation's high resolution scanning electron microscope, the JEOL JSM-6500F serves a dual role: electron beam lithography at the nanoscale and high resolution imaging.

Of particular importance is a Schottky field emission gun that can produce a probe current of up to 100 nA. Probe currents of this magnitude permit pattern writing speeds several hundred times greater than those found with analytical SEM's.



Gold electrode array after resist "lift-off" fabrication step.

*Gold electrode array prepared for studies of IR emission from carbon nanotubes by J. Misewich, S. Wong, A. Stein & J. Warren*

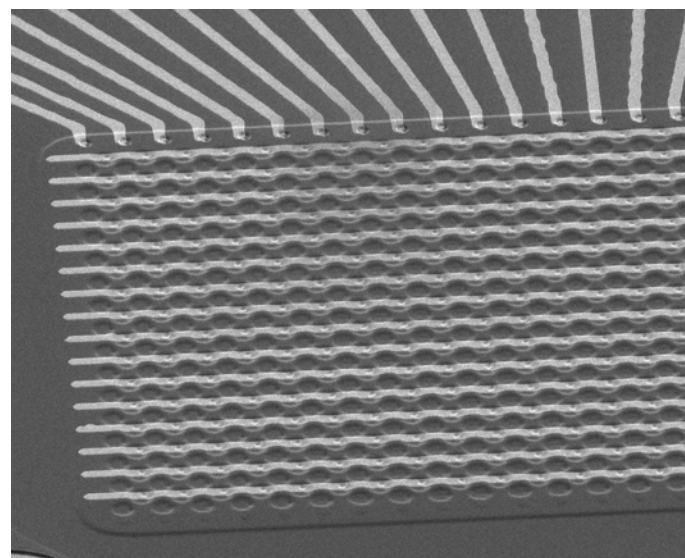


The JSM – 6500F high resolution imaging capabilities are shown with a micrograph of a Strippixel detector fabricated for NASA used in ion beam damage studies.

Wafers up to 6" in diameter can be inserted in the chamber and the entire wafer area can be examined at nanoscale resolution.



4" wafer prior to insertion into chamber



Micrograph of Strippixel array fabricated by Z. Li and D. Elliott in the Semiconductor Detector Facility

# ***Collaborations outside BNL***

## **Non-DOE Federal Agency**

- **National Space Biomedical Research Institute (NSBRI), “Micron Resolution Detector”, V. Radeka, Z. Li.**

## **Other National Labs**

- **Los Alamos National Laboratory, “Application Specific Integrated Circuit (ASIC) for Coplanar Grid (CPG) CdZnTe”, PI: P. O’Connor**
- **ANL, Neutron Detector, PI: G. Smith**
- **SNS/ORNL, Neutron Detectors, PI: G. Smith**
- **NIST, Neutron Detectors, PI: G. Smith**

## **CRADAs**

- **Advanced Energy Systems, PI: T. Srinivasan-Rao**
- **Symbol, Integrated Imaging ASIC, PI: P. O’Connor**
- **eV Products, Readout ASICs for CZT Detectors, PI: P. O’Connor**

## **SBIR subcontract**

- **Photon Imaging, Readout ASICs for gamma camera, PI: G. De Geronimo**

## **Work for Others**

- **Frequency Electronics Inc., Radiation Effects Testing, J. Kierstead**
- **Advanced Energy Concepts, Si Detector Technology, Z. Li**

# Grants for Projects from Diverse Sources

## **Non-Federal Agency**

- **National Space Biomedical Research Institute (NSBRI), “Micron Resolution Detector”, V. Radeka, Z. Li.**

## **Other Labs**

- **Los Alamos National Laboratory, “Application Specific Integrated Circuit (ASIC) for Coplanar Grid (CPG) CdZnTe”, PI: P. O’Connor**
- **ANL, Neutron Detector, PI: G. Smith**
- **SNS/ORNL, Neutron Detectors, PI: G. Smith**
- **NIST, Neutron Detectors, PI: G. Smith**

## **DOE/OBER**

- **Biophysical Instrumentation Research, KP1101010, PI: G. Smith**
- **Medical Applications Instrumentation (PET), KP1401030, P. O’Connor, J.F. Pratte**

## **CRADAs**

- **Advanced Energy Systems, PI: T. Srinivasan-Rao**
- **Symbol, ASICS, PI: P. O’Connor**
- **eV Products, ASICS, PI: P. O’Connor**

## **Work for Others**

- **Frequency Electronics Inc., Radiation Effects Testing, J. Kierstead**
- **Advanced Energy Concepts, Si Detector Technology, Z. Li**

# Mission vs Funding

- Grants from diverse sources are clearly beneficial as they broaden the scope of work and make available the Division's expertise to other institutions. They should be pursued to **augment** the base Instrumentation program supported by G&A, and **they must not detract** from supporting BNL research program and core technologies.
- Benefit of Instr. Div. to BNL (“and the community at large”):

Provide technology base and expertise, and serve as **a resource for important programs and initiatives**, such as **RHIC experiments, electron cooling, ATLAS/LHC upgrades, LSST, Linear Collider, as well as for NSLS, detectors at SNS, nanotechnology, and medical imaging**.